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WATER SUPPLIES AND WATERSHED MANAGEMENT IN THE OLDMAN RIVER BASIN, ALBERTA

by

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ABSTRACT

Potential needs for suitable water supplies in the Prairie Provinces can only be met efficiently through planned water use in the Saskatchewan-Nelson River basin and careful management of runoff on the eastern slopes of the Rocky Mountains. Adverse features of streamflow in the Oldman River basin of southwestern Alberta can be partially modified by effecting changes in the water balance on the area's watersheds, though a programme of preservation, restoration and intensive research must necessarily precede any attempt to do this. As a necessary preliminary to this approach, the patterns of surface water resources in the basin are examined in terms of variations in the water balance from place to place. The achievements of the Eastern Rockies Forest Conservation Board are considered relative to its stated objectives, the Board's concept of multiple-use and the present condition of watersheds on the eastern slopes. Priorities and pre-requisites for effective implementation of those directives are then examined.

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CHAPTER 2

WATER REQUIREMENTS FROM THE OLDMAN RIVER DRAINAGE BASIN

In an average year the Oldman River drainage contributes over two and a half million acre-feet of water to the South Saskatchewan River. It forms part of an interprovincial and international system which eventually discharges into Hudson Bay. Further, it includes an important portion of the relatively small Saskatchewan River headwater areas. These headwaters contribute most of the dependable supplies of water available for irrigation, power, municipal, industrial and other purposes downstream. A brief survey of the processes by which water is apportioned among users and of the actual uses and allocations present in the Oldman basin lends perspective to the discussion in later chapters of the Eastern Slopes as an important watershed. It also serves to introduce problems facing governmental involvement in water resource development in the task of maximizing net satisfactions to society, presumably the aim of any resource management practice.

On its formation in 1948, the Prairie Provinces Water Board, a joint federal-provincial agency, was instructed, inter alia, to

> recommend the best use to be made of interprovincial waters in relation to associated resources in Manitoba, Saskatchewan and Alberta, and to recommend the allocation of water use between each such province of streams flowing from one province into another.[1]

Some twelve years later, the Prairie Provinces Water Board, faced with a lack of information regarding possible lines of development in the

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[1] Agreement signed by the Governments of Canada, Manitoba, Saskatchewan and Alberta, July 28, 1948.

Saskatchewan-Nelson Basin, and realizing that a plan of development should be prepared, circulated an outline for a programme of survey and data collection, so that ultimately "each new proj ct can be integrated with existing and future projects with the best use of water and associated resources as the ultimate goal."[2] On the basis of this reconnaissance report, a resolution was recently submitted by the Board to the Governments of the Prairie Provinces and of Canada

> urging the implementation of a study designed to formulate an integrated-development plan for the water resources of the Nelson River basin. The necessity for such a plan is indicated by the increasing competition in the basin for the use of the water resources.[3]

In the absence of such a guide, provincial water-right administration has issued licences for all "reasonably good" projects, priorities being allotted with strict regard to respective dates of application. Legislation to ensure the protection of legal rights to water both regulates its use and sets out a priority sequence for the various types of use. As stated in the terms of Alberta's "Water Resources Act":

> II. 1. Upon application being made therefor as provided in this Act and the regulations
> a. the right may be acquired to divert any water for domestic, municipal, irrigation, waterpower and other purposes. . . . .
> 2. Such applications have precedence according to the dates of their filing with the Minister . . . .
> 3. Where applications are filed on the same date they have precedence in the following order: first, domestic purposes; second, municipal purposes; third, industrial purposes; fourth, irrigation purposes; fifth, waterpower purposes; and sixth, other purposes.[4]

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[2] Currant, C.F., Preliminary Report on an Integrated Basin Plan for the Saskatchewan River Basin and the Nelson River, Prairie Provinces Water Board, Regina, 1960, p.3. (Mimeo for internal circulation only).

[3] Canada, Dept. of Northern Affairs and National Resources, Annual Report 1960-61, Ottawa, 1961, p. 63.

[4] R.S.A. 1955, c. 362, s. 11.

this provision of allowing a "higher type" of use to usurp the priority of a "lower type" among a particular day's applications implies that the need be demonstrated and damages paid. As the chances of applications being filed on the same day seem rather remote, this provision would appear redundant. The right has, however, been taken to reserve any unappropriated waters, so that allocations may be readjusted amongst the applicants in any manner deemed "best in the public interest."[5] Legislation has gone even further, and Oisvold notes that, "since most water uses today are dependent on allocation by administrative decision or expropriation, it follows that the leading principle of the law pertaining to water is the principle of most beneficial use."[6] However, past interpretation of this principle by the Province, together with pressure from vested interests to uphold the doctrine of prior appropriation when it is in their interests to do so, hardly promote confidence in future water resources development.

Use of water for "domestic purposes" in the Alberta Water Resources Act means that for household, sanitary and fire protection requirements, the watering of livestock and the working of agricultural machinery by others on the land of the riparian owner. Water supplied to a city, town or village is considered a municipal, not a domestic, use. Requirements in this first category are fulfilled by small impoundments of surface water and those riparians drawing from a fairly permanent stream. Groundwater supplies are used in some areas, but

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[5] A.S.A. 1955, c. 302, s. 12 (1).

[6] Oisvold, P., A Survey of the Law of Water in Alberta, Saskatchewan and Manitoba, Canada, Dept. of Agriculture, I.A.R.A. and Economics Division, Ottawa, 1956, p.19. cf. Caffrey, M.M., Comparison of Market Pricing and Other Means of Allocating Water Resources. Addendum to the Southeastern Water Law Conference, Athens, Georgia, Nov., 1961, 20 pp. (mimeo.)

owing to lack of data the potentiality of this resource for meeting future domestic demands cannot be estimated with any accuracy. Whilst the number of these domestic projects is large, actual consumptive use of water is relatively small (see Table 1), and the major problem concerns the search for adequate, dependable local supplies. Almost all of the 47 appropriations licensed for domestic use in the Oldman River Basin in 1962 were for less than one hundred acre-feet each, and "such domestic use occurs principally near the headwaters of small streams causing very little effect on the flow of such rivers as the South Saskatchewan, which derive most of their flow from mountain regions."[7] Increased usage of water under this category continues to follow population growth and the evolution of agricultural practices, so that some storage and diversion will be necessary to ensure an adequate water supply.

"Municipal purposes", second in the priority sequence, denotes household and sanitary purposes, the watering of animals, the watering of streets, walks and paths, fire protection, the flushing of sewers, the use of water for the construction of building and civil works and other, miscellaneous, purposes. The effective daily consumption per capita served by a municipal waterworks system is a direct function of urban population. Assuming an eighty per cent reflow, it is approximately twenty gallons. In the Oldman River basin, including both Lethbridge and Taber, present demand of this class only amounts to about eight thousand acre-feet per year, though a much greater flow is required to maintain an adequate dilution of sewage and industrial wastes.

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[7] Canada, Dept. of Agriculture, P.F.R.A., Irrigation Development Possibilities in the Oldman River Basin, Hydrology Report No. 1, 1952, p. 3.

TABLE 1 - LICENSED WATER APPROPRIATIONS WITHIN THE OLDMAN RIVER BASIN, JULY, 1962.
(In acre-feet)

Category	Total Licensed Appropriation	Per cent of Total Appropriation	Appropriations of less than 100 acre-feet.
Domestic	4,530	0.4	3,075
Municipal	4,130	0.4	285
Industrial	15,770	1.4	300
Lethbridge[a]	29,080	2.6	
Irrigation, excluding the Irrigation Projects	72,565	2.0	7,205
Irrigation Projects[b]	1,031,000	93.2	
Total	1,106,445	100.0	10,935

Source: Bruvy, ..., An Analysis of the Licensed Appropriations within the Oldman River Drainage Basin, Alberta, Dept. of Agriculture, Water Resources Branch, Edmonton, 1962, p. 2. (a) 10,830 acre-foot municipal, together with 18,250 acre-foot of undifferentiated industrial and municipal. (b) St. Mary-Milk River Project, United Irrigation District, Lethbridge Northern I..., Mountain View I. ..., Leavitt I..., Aetna I... and Monlead I....

Table 2 lists the principal urban centres which use or will use water from the Oldman River system.[8] At present, industrial needs served by a municipal supply are included within the municipal appropriation, and for the most part their total consumption of water is not a major item. Estimates of municipal water needs for the year 2000, as suggested in the Integrated Basin Plan, must be based upon an analysis of population trends, especially as affected by the recent emphasis on industrial development on the Prairies. Also, assessments are required of the factors contributing to per capita consumption rates, the significance of water quality requirements under conditions of increased pollution, and advances in pipeline technology. Municipal consumption will always be met, even though other uses must be replaced.

Lethbridge is by far the most important urban consumer of water in south-western Alberta. Average per capita consumption rates remained relatively stable at about 112 gallons per day during the period 1947 to 1960, which saw little major industrial development, but a population increase of 105 per cent.[9] Peak water requirements for domestic and industrial use, as registered in July 1960, were equivalent to twenty c.f.s., while the minimum flow catering for proper dilution of sewage effluent should be about two hundred and fifty c.f.s.[10] However, with present storage facilities and maximum irrigation demand, flow could be

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[8] A basis for future use estimates is contained in Underhill, A.J., Future water requirements for Municipal and Industrial Use in Alberta, Alberta, Dept. of Agriculture, Water Resources Branch, Calgary Dist. Office, 1961, 42 pp.

[9] Oldman River District Planning Commission, City of Lethbridge General Plan, 1960, Analysis of the Survey, Part 3, 1960, p. 23.

[10] Alberta, Dept. of Public Health, Division of Sanitary Engineering, Report on Pollution Survey of the Oldman River Drainage Basin and South Saskatchewan River Basin, Edmonton, n.d., p. 3.

Table 2 - [illegible] 1959 1960.

Centre	Source of Supply	Water Requirements, 1959 (acre-feet per year) Mun.	Ind.	Sewage (a).	Total	Consumptive Use	Average Required c.f.s.	Water Requirements, 1960 (acre-feet per year) Mun.	Ind.	Sewage (a).	Total	Consumptive Use	Average required c.f.s.
Blairmore	York Ck.[a]	213	150	4930	5295	25	[illegible]	331	1200	6175	7706	55	10.6
Bellevue	Crowsnest R.	135		3125	3260	35	4.5	135		2500	2634	50	3.6
Cardston	Lee Ck.	283	300	6660	7203	[illegible]	10.0	456	1000	8500	9956	91	13.6
Claresholm	Willow Ck.	272	150	6295	6717	91	9.2	418	1150	7800	9368	147	12.8
Coaldale	Oldman R.	260	300	6012	6572	91	9.0	549	1600	10250	12399	139	17.0
Coleman	Oldman R.	169	300	3915	4384	23	6.0	230	1600	4300	6130	54	8.4
Fort Macleod	Oldman R.	261	300	6050	6611	32	9.1	436	2250	8125	10811	89	14.8
Lethbridge	Oldman R.	4920	11100	81955	97975	514	134.0	10150	30000	143000	193150	1175	264.0
Magrath	Groundwater[a]	149	100	3455	3704	18	5.1	205	500	3825	4530	43	6.2
Pincher Creek	Pincher Ck.	265	300	6130	6695	31	9.2	724	2000	14500	16224	68	22.2
Taber	Oldman R.	423	1000	9788	11211	62	15.4	938	4000	17500	22438	174	30.1
Waterton Park	Cameron Ck.	168	[illegible]	3750	3918	17	5.4	403		7500	7903	40	10.8

Source: Underhill, J.G., Future Water Requirements for Municipal and Industrial Use in Alberta, Alberta, Dept. of Agriculture, Water Resources Branch, Calgary District Office, 1961. (a) In 1980, the supply sources for Blairmore and Magrath should respectively be the Crowsnest and St. Mary Rivers.

reduced to a total of one hundred and twenty-five c.f.s. in a dry year. To date, a minimum of two hundred and forty c.f.s. has been received at all times, assured until the St. Mary and Milk River Development uses all its allocation of water.[11] An increased, regulated flow and additional water treatment facilities will clearly be needed at Lethbridge in the near future. Given the projected population of 65,000 in 1[illegible], these fifty c.f.s. at least will be required for domestic and industrial needs. Other major centres are not likely to encounter serious water-supply problems, though both Medicine Hat and Magrath will have to rely increasingly upon streamflow resources, and also, some regulation of Willow Creek will be required to offset periodic low flows.

Industrial consumption comprises the operation of railways, factories, stores and warehouses, but does not include the sale or barter of water for such purposes. These uses of water have developed from a phase of steam generation to one of light urban industries and now to newer enterprises such as petro-chemicals. A prerequisite for any industrial expansion is an adequate, proven, relatively unpolluted water-supply, both for cooling and for use as process water, and this must be realized in any estimation of future developments within the area. The effects of pollution by contaminated process water need consideration and a study should be made of streamflow regulation to solve this problem. Prior to the drafting of any integrated plan of development for the basin, it is imperative that future industrial requirements be carefully evaluated.

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[11] Oldman River District Planning Commission, op. cit., p. 23.

Water appropriations specifically for industrial use are dominated by the Kootenay Power Company, which returns eighty per cent of its estimated use of 1,720 acre-feet of water per year to Crowsnest Lake, and the International and McGillivray Coal and Coke Companies, which respectively return a similar proportion.[12] Industrial expansion in the City of Lethbridge will increase per capita consumption there, especially as the locating industries (food and agricultural product processing or manufacturing) require large quantities of water. Fortunately, though, wastes from the important canning industry and sugar refinery occur in the period when the river is open.[13] It has been estimated that the demands of the two new meat processing plants may constitute over twenty per cent of Lethbridge's average daily water consumption in 1969.[14]

About ninety-three per cent of the total licensed water appropriations in the Oldman River basin in 1962 were for irrigation, chiefly in the St. Mary and Milk River Development and the six Irrigation Districts listed in Table 1. The existing irrigable acreages in these projects total over 425,000 acres, while the ultimate irrigable area is estimated by the Prairie Farm Rehabilitation Administration at nearly 800,000 acres (see Table 3).[15] In 1949, the Government of Alberta

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[12] Murray, A.W., An analysis of the licensed appropriations within the Oldman River Irrigation Area, Alberta, Dept. of Agriculture, Water Resources Branch, Lamonton, 1962, pp. 2-5. (unpublished ms.).

[13] Southiller, P.M., and R.L. Wagg, Stream Pollution and its Control in Alberta, Engineering Journal, Vol. 43, No. 6, June 1960, p. 63.

[14] Oldman River District Planning Commission, op. cit., p.24.

[15] Murray, op. cit.

TABLE 3 - [illegible] IN THE [illegible] RIVER BASIN

Name	Year Begun	Status	Irrigable Area		Storage Capacity	
			Existing	Ultimate	Existing	Ultimate
			(thousand acres)		(thousand acre-ft.)	
United I.D.	1921	Under Dev.	21	34		
Mountain View I.D.	1925	Under Dev.	3.6	4.2		
Leavitt I.D.	1943	Under Dev.	2.3	7		
Etna I.D.	1945	Under Dev.	0.1	8		
Macleod I.D.	1948	Under Dev.	2.5	27		
St. Mary Project	1901	Under Dev.	296	510		
Lethbridge N.I.D.	1922	Under Dev.	73	96.1		
Todd Ck. Project		Succ.		5.6		
Pincher Ck. Project		Succ.		16.2		
Beaver Ck. Project		Succ.		2.6		
Cowley Project	1952	Under Dev.	0.8	3.0		
Pekanum Project		Under Dev.		4.5		
Carmangay Project		Under Dev.		12		
Champion Project	1954	Under Dev.	25	50		
Waterton Res.	1959	Under Const.				140
St. Mary Res.	1947	Exist.			320	320
Jenson Res.		Exist.			14[a]	14[a]
Chin Res.	1955	Exist.			50[a]	150[a]
Horsefly L. Res.	1949	Exist.			6	
Taber L. Res.	1949	Exist.				
Pincastle Res.	1950	Exist.				4
Drumm L. Res.	1952	Exist.				
Echo Res.		Exist.			40[a]	40[a]
L. Macgregor Res.		Exist.			150[a]	150[a]
Travers Res.	1951	Exist.			265	265
Little Bow Res.		Exist.			20	30
Pincher Ck. Res.		Under Dev.				5
Bay		Under Dev.				90
Castle L. Res.		Under Dev.				70
Castle L., Canyon Res.		Under Dev.				
Gladstone Ck. Res.		Under Dev.				1
Five Mile Ck. Res.		Under Dev.				3.5
Willow Ck., Chain L. Res.		Under Dev.				13
Willow Ck. Pine Coulee Res.		Under Dev.				26
Trout and Muddy Round Ck. Res.		Under Dev.				7.7
Buffalo L. Res.		Under Dev.				300

Source: Durrant, E.F., Preliminary Report on an Integrated Basin Plan for the Saskatchewan River [illegible] the Nelson River, Prairie Provinces Water Board, Regina, 1960. (a) live storage.

submitted a successful request to the Prairie Provinces Water Board for an allocation of some 2,237,000 acre-feet per year from the South Saskatchewan River to serve existing irrigation projects. Roughly half of this was to be used in the seven areas noted. It has been estimated that the net withdrawal of water for irrigation from the South Saskatchewan in Alberta during 1949, a particularly dry year, was about thirty per cent of the flow,[16] but the effects of return-flow on downstream flow in the Oldman sub-basin can not yet be accurately ascertained. Data from the Eastern Irrigation District and the Bow River Development, relating return-flow to diversion (assuming runoff as 0.5 per cent of precipitation) for the period 1937 to 1961, suggests a consumptive-use of about four-fifths of the water applied in irrigation.[17]

Unlike the other priorities, irrigation demands, being tied to summer moisture deficits, are restricted to a particular time of year, after the peak discharges of both prairie and mountain streams have passed. Consequently, storage projects are important components in the development of irrigation in the basin. It is significant to find the Deputy Minister of Mines and Resources in Manitoba discussing in 1948 irrigation diversions from the Saskatchewan River in Alberta and Saskatchewan in terms of electric power lost to his own Province.[18]

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[16] Laycock, A.H., Water Supply of the Saskatchewan River Basin; Its Source, Use and Conservation, Eastern Rockies Forest Conservation Board, Calgary, 1954, p. 4. (unpublished ms.).

[17] Canada, Dept. of Northern Affairs and National Resources, Water Resources Branch, Report on Return Flows from Irrigation Districts in Alberta, 1937 to 1961, Calgary, 1962, fig. 1.

[18] Stephens, D.W., The Saskatchewan River and Manitoba's Water Problem, The Dominion Journal, Vol. 31, No. 9, Sept. 1948, pp. 470-473. Kuiper estimates the potential loss at electricity worth 36 3/4 millions a year. (Canada, Dept. of Northern Affairs and National Resources, Resources for Tomorrow Conference, Conference Background Papers, Vol. 1, Ottawa, 1961, p. 342.

Within the Oldman River basin itself shortages and water conflicts have not yet become critical. Shortages in the St. Mary tributary basin, such as that occurring in the summer of 1949, have been curtailed with the construction of the St. Mary Dam. Respecting current expansion of the St. Mary Project, diversions from both the Belly and Waterton Rivers are necessary, as Canada's apportionment of roughly half[19] the flow of the St. Mary and Milk Rivers is insufficient to irrigate all the land visualized in Alberta's 1949 request.

The "non-consumptive" use of water for power production ranks fifth in the priorities given to the various water users in Alberta. Unlike the Bow River system, to-date there are no developed hydro-electric power sites in the Oldman basin, though several locations have been proposed. These are noted in Table 4. Were these resources to be utilized, the effect would be to increase streamflow during times of peak power load and to decrease it (through storage) during periods of low power demand. As peak power loads would occur in winter-time, peak streamflow (excluding spillway discharge) would be at the same time, and this water could be used for irrigation only through additional storage. However, fairly constant summer power loads help maintain a good summer flow, which is of some value to the development of irrigation, though it does not alter the overall conflict of interests.

Use of streamflow for other purposes downstream is generally unimportant, non-consumptive and non-competitive. Recreation, especially fishing, would be enhanced by storage development and a stabilized streamflow. Navigation is unimportant.

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[19] Agreement of the International Joint Commission (October 4,1921) set up by a treaty between the United States and Great Britain relating to Boundary Waters, and questions arising between the United States and Canada, signed at Washington, January 11th, 1909.

Table 4 - [illegible]

Site	Storage Capacity (thousand acre-feet)
Castle River Canyon	40.0
Castle River	30.0
Ale Gap	20.0
Willow Creek, Pine Coulee	26.3
Pincher Creek	5.0
Gladstone Creek	1.0
Five Mile Creek	3.5
Trout and Muddy Pound Creek	7.7
Willow Creek, Chain Lakes	17.0
Mill Creek, Site No. 1	
Mill Creek, Canyon Site	
Kelly River	
St. Mary River	
Roe Creek	
Pit Creek	
Waterton River	
Oil Creek	
Blackiston Creek	
Crowsnest River	

Source: Current, B.K., Preliminary Report on an Integrated Basin Plan for the Saskatchewan River Basin and the Nelson River, Prairie Provinces Water Board, Regina, 1960.

CHAPTER II

SOME ADVERSE FEATURES OF THE PRESENT STREAMFLOW

If present and potential requirements for suitable water supplies in the Oldman River basin are to be met, there is need for examination of the relationships between the patterns of water supply and demand before suggesting modifications to the existing system. Drought is a major concern in the basin, both in view of the large seasonal needs for irrigation in drier years, and also owing to the increasing demands for waste disposal. Hence the stress in the Act setting up the Eastern Rockies Forest Conservation Board upon maximization of streamflow from the Eastern Slopes, presumably to be linked with increased artificial storage in downstream areas (see Chapter VII). Intimately related to this requisite for regime improvement are the questions of flooding, erosion and sedimentation, the last of which bears upon the important problem of water quality.

Five high-priority water problems merit attention, all of them common also to the Missouri and Columbia River Basins in the United States, i.e. the control of snowmelt floods; the prevention of sediment in stream channels, reservoirs, water-supply systems, irrigation structures and on farm lands; improvement of late summer water supplies for irrigation; the increase of winter streamflow for potential power generation; and prevention of

local flash floods from high-intensity summer rainstorms.[1] The nature and causation of runoff in the basin are discussed below, and comment here is concerned chiefly with the need for a degree of regime control in the Oldman system. Such control is necessary

> because under natural conditions water is rarely yielded in ways that are entirely satisfactory so far as man's activities are concerned....If water were under complete control there would be no floods where floods mean damage or wasted water; water would be delivered sediment-free to holding reservoirs and diversion points; and all water beyond that necessary to supply the needs of lands and soil protection upstream would be available for use downstream.[2]

There is, however, seldom any economic justification for complete regulation, either to provide near-average flows during extreme droughts or to moderate infrequent flood flows.

Throughout the area, streamflow varies considerably both from year to year and from season to season, though there are distinct areal differences in degree.[3] This pattern of variability and marked seasonality is not in accord with the water requirements outlined above, which would generally necessitate improvement of flow regimes and water quality, with increased annual water-yields as the long-term objective. The extent to which supply can be geared to future

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[1] Packer, P.E., Watershed Management Problems and Research Needs in the Northern Rocky Mountain Region. Paper presented to the Annual Meeting of the Montana Conservation Council, Kalispell, Montana, May, 1957, p. 4. (unpublished ms.).

[2] Coleman, E.A., Vegetation and Watershed Management, The Ronald Press, New York, 1953, pp. 4-5.

[3] Laycock, A.H., Precipitation and Streamflow in the Mountain and Foothill Region of the [illegible], Prairie Provinces Water Board, Report No. 6, Regina, 1957, pp. 25-27 and 32-33.

demands for water depends upon the successful management of the basin's water resources and the establishment of a suitable compromise amongst conflicting needs. Whatever the nature of the decision in allocating water-use rights, downstream requirements must be taken into account. To digress, in connection with these two objectives, a need is apparent for courage in classifying and using the provisions of the existing legal framework and in formulating a development plan to ensure the greatest benefit possible to all the people affected by water use from the system. Problems of definition concern such questions as the meaning of irrigation allocations and the quantities of water which may be diverted over short periods of time. Do the allocations refer to consumptive use of water or to the actual diversions to be carried out? If they mean the former, then how is the legal duty of water, set at eighteen inches for deliveries to the farmers' headgates, reconciled with diversions of over five times that amount in some of the smaller projects in recent dry years, and of twenty-four inches in the larger St. Mary Project in 1961.[4] If they mean water actually consumed, as they would seem to, should not there be stipulations about efficient use of the resource. Study of the way Alberta's legal allocation structure was tested during the 1961 water-shortage on the Bow River serves to emphasize these priorities.

Initially, steps towards water-yield control should cope with reduction or eradication of the destructive effects of the present

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[4] The diversions of water for irrigation and areas irrigated during the period 1959-61 in the major irrigation areas are listed in Table 5.

TABLE 5 – DIVERSION AND AREA IRRIGATED IN ALBERTA 1955–1961
BY THE MAJOR IRRIGATION AREAS

Year		St. Mary Project	Lethbridge Northern I.D.	United I.D.	Raymond I.D.		Mountain View I.D.
1955	Diversion[a]	196,960	46,770	17,700		5,930[c]	
	Area Irrigated[b]	159,700	33,050	10,115	423		3,132
1956	Diversion	210,430	46,900	20,460		12,910	
	Area Irrigated	143,000	31,390	11,082	852		2,773
1957	Diversion	327,670	114,240	26,950		16,680	
	Area Irrigated	149,000	52,110	15,256	2,779		2,773
1958	Diversion	334,400	86,860	22,380		11,340	
	Area Irrigated	178,000	52,220	11,032	1,542		2,759
1959	Diversion	285,850	88,700	25,490		12,250	
	Area Irrigated	174,000	46,760	17,761	1,542		2,789
1960	Diversion	371,340	117,380	26,560		17,420	
	Area Irrigated	192,000	71,310	16,536	1,542		2,789
1961	Diversion	521,350	105,000	23,840		22,460	
	Area Irrigated	214,000	73,940	23,035	1,542		2,789

Source: Pers. comm. the individual Irrigation Districts for acreages irrigated and P.F.R.A. (Lethbridge) for diversion data.
(a) Diversion. (b) Area irrigated. (c) Diversion for the Mountain View, Leavitt and Aetna Projects. Diversion in acre-feet and area irrigated in acres.

system. Management objectives themselves differ from area to area, and will partially depend upon the changing relationship of the various demands for water to present and future supplies. An analysis of problems similar to that prepared by Wilm and Dunford for Region 2 of the United States Forest Service (Colorado, Wyoming, western Nebraska and South Dakota) would be of the utmost value in stressing priorities for different areas.[5] Problems relating to the elucidation of such objectives are discussed below, chiefly in connection with the accomplishments of the Eastern Rockies Forest Conservation Board.

Some of the more conspicuous results of mis-management, or rather lack of management, of water resources in southwestern Alberta, the periodic floods and droughts, could be significantly ameliorated through the mutual interactions of vegetative effects and structural works. Severe flooding has affected parts of the Oldman basin several times during living memory, and damage wrought by the last of these, in 1953, was estimated at a very conservative $1/2 million.[6] In the adjacent State of Montana the flood of May-June 1953, the most destructive ever from the standpoint of monetary loss, caused over $8 1/2 millions of damage.[7] These estimates of flood losses are

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[5] Wilm, H.G., and E.G. Dunford, Problem Analysis - Region 2, United States Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 1948.

[6] Canada, Dept. of Northern Affairs and National Resources, Water Resources Branch, Floods in the South Saskatchewan River Basin 1953. Calgary, 1957, p. 19. (mimeo.).

[7] United States, Dept. of the Interior, Geological Survey, Water Supply Paper No. 1420 - B, Floods of May-June 1953 in Missouri River Basin in Montana, 1957, p. 806.

confined only to the more easily assessed results such as damage to irrigation and flood control works, bridges, railway lines and urban property. A far more realistic appraisal would take note of the depleted land and watershed values which inevitably resulted from such conditions, more so when the land itself has been rendered particularly unstable through past misuse.

While water supplies are at present generally adequate for downstream use, seasonal distribution is sometimes poor, and storage will soon be essential in order to provide more amenable flow regimes. As a small scale example of this, in August, 1962, expensive pumping was necessary to supply Claresholm and Granum when Willow Creek, their erratic water-supply source, stopped flowing. The Creek froze solid during February, 1963, causing a serious water shortage to the 330 residents of Granum. Following this, the Director of the Provincial Water Resources Branch stated that a dam costing $700,000. may be built across the Creek. This would provide important storage during the summer.[8] In this same watercourse, the 1953 flood crest of almost 21,000 c.f.s. was about sixty times the crest in 1949, a low flow year. Low winter flows and ice-cover are an especial concern whenever rivers are required to carry large amounts of waste.[9] In all, twenty-two sites have so far been recognized in the basin, affording almost 1,250,00 acre-feet of

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[8] Calgary Herald, February 8, 1963.

[9] Southhilder, I.H., and H.J. Hogge, Stream Pollution and its Control in Alberta, Engineering Journal, Vol. 43, No. 6, June 1960, pp. 37 ff.

existing and potential storage (see Table 3). The function of watershed management is not to be seen as lying in opposition to the development of such storage facilities for two major reasons. Continuous sedimentation would lead to depletion of reservoir storage capacities and high maintenance costs, and also, downstream control works cannot prevent destructive flood peaks and water shortages from affecting both watersheds themselves and upstream rural development.

Water needs must be visualized in terms of potential, not actual, demand, if effective satisfaction is to be planned, especially as streamflow may prove to be a major factor limiting future economic development in the Saskatchewan-Nelson River Basin. It is consequently imperative that there should be an

> application of business methods and technical principles to the handling of all the renewable resources in a watershed to assure maximum supplies of usable water, desirable waterflow, prevention and control of erosion, and the reduction of flood and sediment damages.[10]

Part of the watershed of the Oldman River system has been, and still is, administered by authorities whose main objective for management is not watershed improvement. The Waterton-Glacier International Park is devoted chiefly to recreational purposes, and the private lands of the foothills and plains are given over primarily to farming and ranching. In the latter, however, provisions have been

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[10] Quoted by Jeffrey, ..., Prerequisites and Priorities for Watershed Research in the Eastern Foothills, Alberta, Canada, Dept. of Forestry, Forest Research Branch, Calgary, 1961, p. 1. (unpublished ms.).

made under which the Provincial Minister of Agriculture may direct or order

> that such steps be taken as he thinks necessary for the protection of the sources of water supply and the prevention of any act likely to diminish or injure the supply.[11]

The Crowsnest Forest Reserve has as its main purpose management for optimum flow regimes, but is used in a number of ways, though these do not necessarily conflict with the stated aim.

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[11] R.S.A., 1955, c. 302, s. 79 (3).

CHAPTER III

THE WATER BALANCE AND ITS QUALIFICATION

"Every unit of land, however small, is part of a watershed. Hence the manner in which the land is managed will inevitably have some influence on streamflow."[1] So as to understand the basis upon which watershed management is to be carried out, some appreciation of the water balance concept and the way in which it can be applied to water resource development is desirable. With reference to larger drainage basins of the type under discussion, gains and losses of water can be conveniently framed within an elementary water balance equation, i.e. that precipitation equals evapotranspiration (potential evapotranspiration minus deficit) plus streamflow. Further, unless short periods of time are considered, the water storage factor can reasonably be eliminated. Theoretical water yields can then be computed, assuming that sufficient climatic data is available.

Some details of the relationships embodied in the balance merit attention before passing on to examine how elements of the equation can be purposefully or adversely modified. Dealing mainly with the areas of forest and range below the timberline, such relations can be summarized into four groups: (a) interception of precipitation in the foliage and branches of vegetation, if present, (b) infiltration and percolation of water into and through the soil, surface runoff and water storage,

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[1] Lowdermilk, L. et al., Some Plant-Soil-Water Relations in Watershed Management, United States Dept. of Agriculture, Circular No.910, Washington, 1952, p. 46.

(c) transpiration, or use of soil water by vegetation, and

(d) evaporation of moisture from the surfaces of vegetation and the ground. All except the second of these constitute evapotranspiration, "an important mass transfer from ground to atmosphere, the reverse of precipitation in the hydrologic cycle".[2]

Precipitation may be intercepted by vegetation and evaporated back into the atmosphere, depending in amount upon the nature of both the precipitation and the vegetative cover. Annual interception losses from coniferous vegetation tend to be greater than those from a deciduous cover, whilst dense grasses intercept much smaller amounts than either of these. Many other variables complicate this pattern, including the fact that snow is easier to intercept than rain and also that precipitation intensity is an important determinant of interception. Limited relevant experimentation involving selective cutting suggests that interception represents a substantial loss from closely forested areas.

Three things can happen to the precipitation which eventually reaches the ground surface. It may evaporate, run off or enter the soil either for use by vegetation or to become involved in some variety of lateral flow. Infiltration capacities determine the speed with which water enters the soil, and if precipitation intensities are sufficiently great then runoff can occur before storage capacities are filled. This may also occur if percolation capacities are low at some level within the soil. Unlike percolation, which is controlled by subsurface

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[2] Thornthwaite, C.W., and J.R. Mather, The Water Balance, Drexel Institute of Technology, Lab. of Climatology, Publications in Climatology, Vol. 8, No. 1, Centerton, N.J., 1955, p. 15.

conditions, infiltration depends upon the immediate soil surface, the number and size of non-capillary pore-spaces present. "Soils having coarse texture or of large aggregates, a layer of litter and humus on the surface, insects and small animals working in the soil and abundant roots of vegetation to make spaces for water movement and storage have high infiltration and percolation rates."[3] With the occurrence of precipitation intensities of five inches per hour (even for short periods of time) on shallow residual soils in the foothills, the importance of the vegetative cover in reducing rainfall impact and maintaining soil porosity deserves stress.

Infiltration may be limited by some types of soil frost, thus preventing soil-moisture recharge and percolation during snow-thaw. Sometimes, however, the ground is unfrozen beneath deep mountain snowpacks because of particularly large flows of heat from the ground, together with the insulating effect of the snowpacks themselves. The soil's overall permeability, in terms of its infiltration and percolation capacities, is a particularly important determinant of the disposal of precipitation into surface, subsurface and baseflow and the utilization of storage space. Desirable subsurface flow, whether lateral or vertical, is largely determined by a soil's noncapillary porosity and the hydraulic gradient of the flowing water.

Water entering the soil mass to the depth of plant rooting can achieve pore saturation before removal of detention storage reduces this

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[3] United States Senate, Select Committee on National Water Resources, Evapotranspiration Reduction, Water Resources Activities in the United States, Committee Print No. 21, Washington, 1960, p. 19.

to the field capacity. This occurs when further drainage by gravity flow becomes negligible and only water held in retention storage remains for use by plants until the wilting point is reached. Storage potentials within the soil depend largely upon soil texture and depth classes, and also upon the account of organic matter present. Data used by Coleman indicate retention storages per unit soil depth as being five times greater in clayey than in sandy soils, though the former's advantages may be offset by adverse infiltration qualities (see Table 6).[4] However, actual usability of storage space depends upon infiltration and percolation values relative to precipitation intensities and the amount of water already being stored.

Insofar as they cannot occur independently on vegetated areas, the complex processes of transpiration and evaporation cannot realistically be separated.[5] The transpiration to soil evaporation ratio depends over long periods of time upon the relative heat flow to the plant and the soil and the availability of water at these surfaces, that is upon the spacing, size and shape of the plants, the precipitation distribution and the soil's capillary characteristics. These two processes are markedly different in the manner and degree to which they create retention

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[4] Coleman, E.A., Soil Surveying on Wildlands: the Problem and One Solution, Journal of Forestry, Vol. 46, No. 10, Oct. 1948.

[5] Vide Lull, H.W. (ed.), Evapotranspiration: Excerpts from Selected References, United States Dept. of Agriculture, Forest Service Southern Forest Expt. Stn., Occasional Paper No.151, 1959, 117 pp., Humphreys, C.R., Evapotranspiration Bibliography, Dept. of Resource Devt., Agricultural Expt. Stn., Michigan State University, Water Publication No.7, n.d., 53 pp. and Canada, Dept. of Northern Affairs and National Resources, Water Resources Branch, Proc. Hydrology Symposium No. 2, Evaporation, Toronto, Ottawa, 1962, 253 pp.

TABLE 6 - WATER STORAGE VALUES OF SOIL TEXTURE CLASSES [a]

(Inches of water per foot of soil depth)

CLASS [b]	PORE SATURATION	FIELD CAPACITY	WILTING POINT	RETENTION STORAGE	DETENTION STORAGE
Sand	5.0	0.9	0.4	0.5	4.1
Sandy loam	5.0	1.8	0.7	1.1	3.2
Loam	5.0	2.7	1.1	1.6	2.3
Clay loam	5.4	3.4	1.7	1.7	2.0
Clay	5.4	5.0	2.5	2.5	0.4

Source: Colman, E.A., Soil Surveying on Wildlands: the Problem and the Solution, Journal of Forestry, Vol. 46, No. 10, Oct., 1948, p. 760. (a) In Southern California. (b) Apparent density of sand, sandy loam and loam 1.5 gm./cc. and of clay loam and clay 1.4 gm./c.c. used to convert percentage of soil moisture to inches depth of water. Soil density assumed equal to 2.6 gm./c.c. for all soils.

storage opportunities in the soil mass, while differences in transpiration from areas of differing vegetative cover can be largely ascribed to differences in soil depth occupied by plant roots.

One of the main difficulties in estimating the water balance on part of a watershed is that of determining the actual evapotranspiration losses. With assumptions for storage capacities, it can be computed on a monthly basis by using an empirical approach to the determination of potential evapotranspiration, such as that described by Thornthwaite and Mather, which combines empirical coefficients with temperature and day-length data.[6] Use of more sophisticated methods, for example the radiation balance, is precluded through lack of observational data. After making allowances for a variety of factors,[7] Laycock used average monthly temperature recordings from the sparse station network in outlining a generalized picture of evapotranspiration on the Eastern Slopes.[8] Taken with the distribution of precipitation, approximate water yields were determined for the period 1921-50 and these have been extended to 1960. Streamflow measurements provide both a useful check with precipitation of evapotranspiration and also help toward establishing the mean precipitation over a watershed. It is,

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[6] Thornthwaite and Mather, op. cit., pp. 87-104.

[7] These include varying storage capacities, lack of stress on detention storage, varying plant rooting depths, low infiltration rates high precipitation intensities, snowmelt on frozen, unsaturated soil, use of water by plants at varying rates and withdrawal of water by plants from the water table and streams.

[8] Laycock, A.H., Precipitation and Streamflow in the Mountain and Foothill Region of the Saskatchewan River Basin, Prairie Provinces Water Board, Report No. 6, Regina, 1957, fig. 6 (mimeo.)

unfortunately, not at present possible to calculate quantitatively for this area the day to day variations in the values of the detention and retention storage factors, but changes in the amount of water in these two conditions can be roughly estimated in relation to successful regime improvement in the basin which, as noted, represents the main direction in which watershed improvement priorities lie.

By a variety of methods it is theoretically possible to change the magnitude of elements in the water balance at any particular point on a watershed, either unintentionally or with some purpose such as improving water yields or times and amounts of streamflow maxima. Manipulation of the vegetative cover has been extensively studied in the United States with these latter objectives in view, and must be considered, with alteration of the condition or type of soil, the chief method by which the balance can be purposefully changed.[9] As to controlling the precipitation factor, "Much research into the fundamentals of cloud physics and formation of rain and field tests must be conducted under conditions of good scientific design and experimental controls before definite conclusions can be reached as to whether rain and snow can be induced artificially in sufficient quantity to be of much value economically".[10]

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[9] The McSweeney-McNary Forest Research Act (1928) marked the beginning of research into the controversial subject of forest influences on streamflow, which had provoked such heated discussion during the passage of the Weeks Law in 1911. For useful bibliographies of monographs see United States Dept. of Agriculture, Forest Service, Forest and Range Influences, Publications, 1909-1952, Washington, 1960, 11 pp., and Underhill, A.L., Report of the Effect of a Change in Vegetation on the Runoff Characteristics of Alberta Streams, Alberta, Dept. of Agriculture, Water Resources Branch, Calgary, 1962, 97 pp.

[10] United States Senate, Select Committee on National Water Resources, Weather Modification, Water Resources Activities in the United States, Committee Print No. 22, Washington, 1960, p. 3.

The major objective in the area under study is currently to optimize yields, presumably relative to seasonal demand and quality requirement patterns, rather than simple maximization of flow. Overall burning would produce the highest immediate water yields, but the resulting regimes and the effects of surface runoff would be intolerable. Further, as on the majority of western watersheds, other important activities such as timber, forage, wildlife and recreation must be taken into account, together with the rising demands for some of these uses. In other areas, Waterton National Park for example, institutional arrangements are such that large scale vegetative manipulation would be incompatible with the stated management objectives. All these provisions must be appreciated in the over-all planning of action in the individual river basins.

Runoff can be delayed from snowpack zone forests and lower range lands, though were sufficient downstream storage available it would be expected that stress would devolve upon the highest yields of good quality water possible without deleterious effects. Flash floods and major sustained flood flows can both be modified by watershed management practices. High intensity rainstorms or rapid snow release, even when storage is available, can cause destructive overland flow which can be checked by building up a plant and litter cover of maximum density and developing a soil of highest porosity. This curtails surface runoff, maximizes evapotranspiration losses (maintaining large storage opportunities), decreases erosion and sedimentation and prevents channel shoaling. The large discharges over longer periods of time deriving especially from back-range snowmelt and continuous precipitation can

also be mitigated by improving infiltration and detention storage capacities. A dense forest cover aids in delaying snowmelt and keeping the surface porous, though warm rains might render this a likely flood hazard.

With different objectives in view, management of the plant cover can cut water losses by reducing interception, evaporation and transpiration of water from densely vegetated areas through partial removal of trees and / or their replacement with shallower rooting species. Research suggests that forest structure can be geared toward maximum snow accumulation, minimum interception and evaporation of precipitation and retarded snowmelt, and also that these treatments are not incompatible with the aims of good timber management. It should be emphasized that application of watershed management principles need not require extreme changes in land-use or drastic adjustments in timber, forage and wildlife management practices.

Controlled burning might conceivably have a place in management for yield increases, though augmented stream-flows from the snowpack zone should be seen in terms of selective cover removal and species substitution. Regarding the first of these, forest development to reduce interception, evaporation and transpiration losses could utilize techniques of strip and patch cutting, though the effects of rapid regrowth would require attention. Yields might also be increased by the substitution of shallow-for deep-rooted species, giving increases equal to the difference of the retention storage capacity remaining unused. In all, careful vegetative management of the mature snowpack forest on the deeper soil types might increase yields by almost

four inches, or some twenty per cent.[10] Increments of the order of eight inches could accrue from removal of scattered phreatophytic growth in some southern lowland locations, though as in snowpack forest management, the full consequences of any action must be appreciated before it is carried out.[1] Potentialities for improved quantity, quality and regime characteristics are discussed for the respective classes of surface materials in Chapter IV.

However, the compaction of the soil surface which is connected with improper use of forest and range resources tends to reduce infiltration capacities, increase soil densities and reduce storage potentials above and in the soil mantle. Increased surface runoff again leads to sedimentation from accelerated surface erosion, while gully development drains away underground stored water. Clearcutting of timber also stimulates overland flow, though the effect of increasing water yields would be partially offset by greater evaporation losses and use of water by the remaining ground vegetation. Soils become unprotected from rainfall impact, infiltration is decreased and snowmelt quickens. Damage by fire produces very similar results to those of clearcutting, with the added factor of destruction to an important litter cover. In contrast, crown fires in areas of heavy snowfall might lead to appreciable increases in snow storage. The effects of grazing activities on the water-relationships of rangelands chiefly depend upon the degree of forage use which is permitted. Particularly heavy utilization is associated with reduced root growth and decreased availability of retention storage. These already low storage potentials may be only

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[1] [illegible] cited [illegible], op. cit., footnote [illegible].

partly used owing to reduced infiltration rates. Such effects as these can be ameliorated to a critical degree, and stable soil used as an index of successful management, whatever its purpose.

CHAPTER IV

GEOGRAPHICAL BASES FOR WATER RESOURCE PATTERNS

The Oldman River and its tributaries drain a gross area of approximately 9,705 square miles, most of which lies within the Province of Alberta.[1] To the south, the basin is defined by the Oldman-Milk watershed and also by a considerable area of internal drainage east of the Milk River Ridge, between the two rivers. There, part of the runoff flows into Stirling, Tyrrell and Verdigris Lakes, and also through Etzikom Coulee to Pakowki Lake. Northwards, a divide separates the Oldman River basin from that of the Bow, with which latter river the Oldman unites to form the South Saskatchewan at The Grand Forks.

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[1] The "effective drainage area" is of the order of 8,110 square miles. Vide Stichling, W., and S.R. Blackwell, Drainage Area as a Hydrologic Factor on the Glaciated Canadian Prairies, Int. Assoc. of Sci. Hydrology, General Assembly, Rome, Vol. 3, Gentbrugge, n.d., pp. 365-376. Durrant and Blackwell define the effective drainage area as "that area which might conceivably contribute to peak flow in an average runoff year", and the gross drainage area as "that area enclosed within its divide (height of land within watersheds) which would, through natural and artificial processes, entirely contribute to the flood peak under extremely wet conditions". (The Magnitude and Frequency of Floods in Alberta, Saskatchewan and Manitoba, Canada, Dept. of Agriculture, P.F.R.A., Hydrology Division, Regina, 1961, p.16). The discrepancy is especially notable in the eastern part of the basin, with its flat topography, many depressions, and poorly defined channels.

An analysis of the source areas of streamflow in the Oldman River for 1948-49, a relatively dry year when effective drainage areas on the plains were small, illustrates the significance of the mountain and foothill portions of the basin (see Table 7). Comprising under forty per cent of the total area drained by the Oldman system, the lands above four thousand feet in elevation supplied all but three per cent of the total streamflow of about two million acre-feet. Between them, the Eastern Rockies Forest Conservation Board's Crowsnest Forest Reserve and the Waterton-Glacier International Peace Park, just over one fifth of the basin's area, accounted for over ninety per cent of the total streamflow. In view of the potential requirements from the Oldman River Drainage system, the significance of the "Eastern Slopes" as far as the provision of reliable water supplies is concerned, becomes apparent.

THE GEOLOGICAL FRAMEWORK OF THE EASTERN SLOPES

Interacting with the various structural units and their different qualities, processes of weathering and erosion have helped to produce the present complex pattern of landforms. Taking into account significant areal differences in climate, surface materials, and vegetation, a tentative picture of the existing water balance can be gained, a necessary preliminary to any useful watershed research and its eventual application in watershed manipulation to improve streamflow. Discussion is especially concerned with the Crowsnest

TABLE 7 - SOURCE AREAS OF STREAMFLOW IN THE CLARKE RIVER, 1948-49

SOURCE AREA	AREA (square miles)	PER CENT TOTAL AREA	STREAMFLOW (acre feet)	PER CENT TOTAL STREAMFLOW	STREAMFLOW (inches)
Brownsett Forest	1253	12.9	700,000	40.0	11.6
Castlemount	360	4.7	370,000	19.0	13.0
Crowlodge	1	1.4	[illegible]	6.1	11.7
Livingstone	450	4.5	280,000	12.7	10.0
Willow Creek	124	1.3	40,000	2.1	6.7
S. Porcupine	102	1.1	30,000	1.6	6.0
N. Porcupine	[illegible]	[illegible]	10,000	[illegible]	3.1
Waterton Park	220	2.2	220,000	11.3	21.0
United States of America	609	6.2	770,000	40.0	24.1
Foothills	1644	17.1	110,000	5.7	1.6
Plains	5980	61.6	54,750	3.0	0.2
TOTAL CLARKE RIVER BASIN	9705	100.0	1,948,750	100.0	[illegible]

Source: Laycock, A.H., Water Supply of the Saskatchewan River: Its Source, Use and Conservation, Edmonton, 1954, (unpublished ms.) and Murray, [illegible], Alberta, Dept. of Agriculture, Water Resources Branch (pers.comm.). (a) Above 4,500 feet and not in the other areas listed. It is to be noted that 1948-49 was a particularly dry year.

Forest Reserve, giving some perspective to the past and potential developments outlined in Chapters VII, VIII and IX.

The northern Rocky Mountains, which extend from western Montana northwards into Canada, consist of ridges of predominantly sedimentary rocks deformed by a complex system of folds and faults.[2] Precambrian Beltian sedimentaries, including thick limestone formations, are exposed in the Lewis Thrust sheet of southwestern Alberta.[3] Decisively unconformable beneath Middle Cambrian fossiliferous formations, they wedge out eastwards between the crystalline pre-Beltian basement and the miogeosynclinal Paleozoic and Mesozoic rocks which reach a classic development in the latitude of Banff.[4] Strongly deformed during the Laramide orogeny and the disturbances that preceded it, these last are bounded on the east by a foreland which received Cretaceous and Paleocene deposits, and which was warped downwards into the Alberta Syncline. Unlike the southern Rocky Mountains, the two are separated by an intensely deformed "foothill" belt, and also the older sedimentary rocks have

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[2] Vide Southern Rocky Mountains of Canada. Tectonics Compilation Map in Alberta, Society of Petrol. Geologists, Guide Book, Fourth Annual Field Conference, Banff-Calgary-Jasper, 1954 and Ving, P.B., The Evolution of North America, Princeton University Press, 1959, pp. 57 and 132 ff.

[3] Gussow, W.C., Precambrian and Cambrian Geology of Southern Alberta, Alberta Society of Petrol. Geologists, Guide Book, Seventh Annual Field Conference, Waterton, 1957, p. 10.

[4] Clark, L.M., Geology of Rocky Mountains Front Ranges near Bow River, Alberta, Amer. Assoc. Petrol. Geols. Bull., Vol. 33, No.4, 1949, pp. 614-633.

been carried eastwards over younger beds for many miles along long, low-angle thrust faults.[5] The fourth major structural feature underlying the Oldman River basin, with the Rocky Mountains, the "foothills" and the Alberta Syncline, is the Sweetgrass Arch, a part of the broad, stable depositional area between the Williston Basin and the Rocky Mountain Geosynclinal Belt which was upwarped in the Tertiary.[6] Like the whole series of anomalous structures of which the Arch is the northernmost, it was chiefly produced as a result of uplift and igneous intrusions (see Chapter VI).

The eastern slopes of south-western Alberta, approximately the area above an elevation of four thousand feet, can be divided into two structural subdivisions, the general Crowsnest section and the Lewis Thrust area in the south. The former contains five "front ranges",[7] the first of which is underlain by the folded, low-angle Livingstone thrust fault which replaces the McConnell fault south of the Highwood River. All of their underlying faults plunge southwards, exposing gradually younger strata. In the latitude of the base itself, the more easterly front ranges resemble the foothills in

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[5] Alpha, A.G., Tectonic History of North Central Montana, Billings Geol. Soc., Guidebook, Sixth Annual Field Conference, Sweetgrass Arch - Disturbed Belt, Montana, Sept.1955, pp. 130-137.

[6] Kellie, F.J., The Sweetgrass Arch Area - Southern Alberta, Alberta Soc. of Petrol. Geologists, 1957, op. cit., pp. 27-45.

[7] North, F.K., and G.G.L. Henderson, Summary of the Geology of the Southern Rocky Mountains of Canada, Alberta Soc. of Petrol. Geologists, 1954, op. cit., pp. 20-25.

structure and have lost much of their elevation. Intervening Mesozoic rocks become remarkably wide.

Three major stratigraphic groups are represented in this northern area. Resistant limestones and siliceous shales from the Upper Devonian and Mississippian make up such ridges as the Boundary and Livingstone Ranges, both rising over seven thousand feet above sea-level. Lower Cretaceous rocks extend south to the Crowsnest Pass area, exposed in a belt along the Livingstone fault. Compact shales, hard sandstones and finely cemented conglomerates, they are more resistant than the Upper Cretaceous group. Thirdly, the Upper Cretaceous and Tertiary outcrop chiefly in the foothills and plains, but are over-ridden by Mississippian strata along the length of the Lewis Thrust in the Crowsnest section. They comprise soft shales, slightly compacted argillaceous sandstones and loosely cemented conglomerates. The disposition of sandstone parent materials on the foothill ridges is especially important regarding the formation of residual soils there.

In Waterton National Park and the southern Castle District of the Crowsnest Forest there are none of the ranges typifying the sub-parallel structure of the front ranges farther north, owing to comparatively low dips and strongly marked folding.[8] There, hard compact Pre-cambrian quartzites, shales, slates and limestones lie upon the Upper Cretaceous of the Disturbed Belt along the Lewis Thrust.

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[8] Loc. cit.

Common to both sub-divisions, and situated between the front ranges and the plains, the intensely folded and faulted Mesozoic rocks of the "Disturbed Belt" occupy a north-westerly trending strip some ten to twenty miles wide.[9] The southern part of the belt in the Alberta section of the Oldman River basin "looks like a great enlargement of the plains, and with the exception of a small strip close to the mountains, has a relief of only 150 to 400 feet".[10] For a distance of about twenty-five miles north from the International Boundary an unbroken slope extends from the plains to the base of the mountains. The "foothills" variety of structure is present under these "rolling plains" which derive from extensive erosion of the Lewis overthrust.

Farther north, across the Oldman River, the Porcupine Hills are separated from the foothills by the broad, subsequent valley now occupied by the Oldman River, Callum Creek, Swanson Creek and the Chain Lakes. Although structurally a part of the Alberta Plains, the Hills are administratively in the Crowsnest Forest Reserve, and their watershed qualities justify their inclusion in the "Eastern Slopes". They were formed by advanced erosion of the fine-grained sandstones and interbedded shaly clays of the Paleocene Porcupine Hills formation within the Alberta Syncline. Rising in places over two thousand feet above the plains to the east, the well-dissected

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[9] Stewart, J.S., Geology of the Disturbed Belt of Southwestern Alberta, Canada, Dept. of Mines and Technical Surveys, Geol. Survey of Canada, Memoir No. 253, Ottawa, 1950, pp. 4-5.

[10] Ibid., p. 4.

Hills average in elevation from 4,000 to 5,600 feet above sea-level and parallel the Disturbed Belt between townships 9 and 17.[11]

GEOMORPHIC PROCESSES

Summary of the various gradational processes operative on the Eastern Slopes can be organized into three periods: pre-Pleistocene, Pleistocene, and Recent, each making a distinctive contribution to the present pattern of polygenetic landforms, with their varying watershed properties. The major physiographic divisions, whose structural bases were described above, derive from pre-glacial erosion of the variously uplifted bedrock masses, chiefly by water action and gravity. Major longitudinal valleys became established along lines of softer rocks and structural weakness, cutting transversely through ridges via narrow, steep-sided gaps. Where present, the regolith was dominantly residual.

Appreciable changes took place as a result of differing degrees of glaciation by glaciers of local origin, from Laurentide ice and also by eastwards flowing masses from the west of the Continental Divide. With increasing distance to the east, towards the front range of foothills-plains transition, the time and intensity of glacial action gradually decreased, with most "glacial" forms, both erosional and depositional, being well developed in some part of the area. A network of glaciers from the Cordilleran Glacier Complex[12] occupied

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[11] Williams, M.Y., and S. . Dyer, Geology of Southern Alberta and Southwestern Saskatchewan, Canada, Dept. of Mines, Geological Survey, Ottawa, 1930, p. 62.

[12] Flint, ..., Glacial Geology and the Pleistocene Epoch, Wiley, New York, 1947, pp. 302 ff.

the valleys and middle and lower slopes of the higher mountains, reaching their maximum extent in either the first or second regional glaciation (Nebraskan or Kansan). Laurentide ice probably arrived when the mountain ice was already retreating, and their respective deposits are hardly interworked at all.[13] Considerable overlap occurred, especially in the higher "foothills", where Laurentide ice reached elevations over five thousand feet above sea-level. The Porcupine Hills, which prevented Cordilleran ice from advancing eastwards, are covered on their eastern flanks with Laurentide till, though, as in the mountain ranges, high areas remained unglaciated above the highest glacier surface. There was limited contact between the two masses in the last (Wisconsin) advance in the Twin Butte-Mountain View district, and many previously covered areas remained untouched.

By gouging and plucking, ice helped to change the narrow, incised valleys of the back-ranges into wide U-shaped troughs, and erosion of valley head walls formed corries below the sharp-crested ridges. Slopes were undercut and steepened, becoming more concentrated than in the pre-glacial landscape. Valley gradients became irregular, and in general the contemporary and later action of other agents was markedly accelerated. Large amounts of glacial, glacio-fluvial and

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[13] Stalker, A. MacS., Some Features of the Surficial Geology of the Fort Macleod Region of Alberta, Alberta Soc. of Petrol. Geologists, 1957, op. cit., pp. 52-63 and Descriptive Notes, Map No. 21-1958, Fort Macleod (Surficial Geology), Canada, Dept. of Mines and Technical Surveys, Geol. Survey of Canada, 1958 and Allan, J.A., Geology, Part III, Geology of Alberta Soils, Research Council of Alberta, Report No. 34, 1943, pp. 60-146.

glacio-lacustrine material were deposited during this period, with significant consequences for the watershed characteristics of the area. They lie quite deep in the broad, flat valleys, and have been subjected to varying degrees of sorting and reworking since deglaciation. Intensified periglacial processes just below the limits of permanent snow were responsible for the shallow colluvial slopes of coarse, angular fragments of bedrock and surface materials. Extremes of drainage conditions were produced, though storage capacities were improved by the abundant drift and colluvial materials described below.

In the short period since glaciation, the dominantly "glacial" forms have been modified, especially through water action. Large quantities of drift have been washed down into the valleys, where the irregular gradients have promoted an alternation of erosion and deposition along the stream courses. Flood-plains were built up and rivers became deeply incised owing to decreased loads, increased streamflow or changing base-levels, and have produced several levels of terraces, as along the lower Carbondale. Fans were created at the outlets of steeply flowing tributaries. Coarse alluvial materials so deposited have, for example, partially blocked the main-stream of the North Fork of the Crowsnest River. Wind action may have been significant in moving unprotected sands and silts of terraces, and Laycock describes what appears to be an aeolian cap over fine alluvium on one of the more prominent terraces of the Lower Castle, about a mile north of the Castle Ranger Station.[14]

[14] Laycock, A.R., Report of the Soil and Watershed Survey for the Summer of 1952, Eastern Rockies Forest Conservation Board, Calgary, 1953, p. 22.

Breakdown by weathering of bedrock and transported materials has been relatively slow, much of the regolith present being of depositional origin. Little residual regolith has been formed from underlying bedrock. Most of this occurs on the softer rocks to the east, for on the exposed western ranges, water erosion and mass-movement almost balance the weathering processes of mechanical disintegration of porous, highly fractured bedrock and the limited chemical decomposition operative in the cool, dry rock environments of those ranges.

PRECIPITATION

Owing to the sparsity of meteorological instrumentation on the Eastern Slopes, only tentative patterns of precipitation and other climatic elements can be discerned, and indirect methods of estimation (for example, by using streamflow data) are at present determinants of only general differences amongst areas. The use of empirical parameters, such as elevation, aspect and exposure to particular storm tracks, and any satisfactory multiple correlation analysis are prohibited by lack of observations.

There is a considerable variation in local climates, partially caused by the configuration of the terrain and aspect, with a marked trend towards increase in precipitation with increasing altitude. Precipitation totals are greatest in the western ranges, which receive over fifty inches per year on average, and over seventy inches along

some parts of the Continental Divide.[15] The eastern slope of the front range and the low foothills average about thirty inches, while relatively low totals are found in inter-mountain valley locations and on the plains. Coleman, for example, receives an average under twenty inches annual precipitation, and Cowley, on the plains-foothills margin, about the same.

In most years there are significant departures from normal precipitation in at least one season and in at least several parts of the area. Mild and moderately moist maritime Pacific air is dominant, and is subjected to orographic, cyclonic and convectional disturbance. Storms are frequent, but are light and only of short duration. Infrequent incursions of maritime tropical air in late spring and summer from the east (associated with lows slowly moving northwards from Colorado) can bring relatively high intensity storms to the plains, foothills and front ranges, but not the western ranges, where "spill-over" snowfall from acific air masses accounts for the large precipitation totals. Rainfall tends to be moderately frequent, usually light and of short duration, on the eastern slopes of the front range and on the Porcupine Hills. It can, however, be very heavy, as it was in June, 1953, when the light vegetative cover was inadequate to protect the soil surface.

Precipitation in winter between October and May exceeds summer rainfall in the western areas, though farther eastwards the

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[15] Eastern Rockies Forest Conservation Board, Compilation Data from Storage Precipitation Gauges, Crowsnest Forest, (unpublished ms.) lists areal variations in mean annual precipitation from 18.8 to 47.4 inches, though these figures are of questionable validity. They should be interpreted regarding site, exposure, gauge efficiency, etc.

mountains and foothills have greater spring and summer and less winter precipitation. Ogilvie considers the winter maximum-summer minimum regime as characteristic of the Subalpine Forest area, to which he assigns precipitation totals varying from twenty to thirty-five inches.[16] Winter precipitation totals in the Crowsnest Forest Reserve are among the highest recorded in the Eastern Rockies Forest Conservation Board's area. Elevation for elevation, the southern part of the Reserve has about five inches more winter precipitation than the forests to the north of the Crowsnest Pass. The plains receive their precipitation almost entirely as rain, and time of maximum varies with latitude, being greatest in May to early June in the south, and increasingly slightly later farther north. Aperiodic weather disturbances include cold-front cyclonic storms moving from the north-east to affect the whole area, and also the passage of "cold lows" in summertime.

VEGETATIVE COVER

The distribution of species of vegetation in south-western Alberta exhibits great areal variations consequent upon differences in temperature, precipitation, elevation, soil-type, aspect, exposure, drainage, etc., and also through such agencies as insects, disease, fire, competition and use. Forest associations are widespread in the western part of the Oldman River basin, where species from two gross distribution patterns, boreal and transmontane, are found.[17]

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[16] Ogilvie, R.T., Spruce Habitat Types in the Eastern Slopes of the Rocky Mountains, Canada, Dept. of Northern Affairs and National Resources, Forestry Branch, Forest Research Division, Calgary, 1961.

[17] Iden., Notes on Plant Distribution in the Rocky Mountains of Alberta, Canadian Journal of Botany, Vol. 40, 1962, p. 1091.

Two timber-lines are present, a lower one resulting from periodic moisture deficits located roughly along the Forest Reserve's eastern boundary, and an upper one due to low temperatures at about eight thousand feet above sea-level.

The Subalpine Forest,[18] which is the most extensive forest type in the basin, is predominantly composed of the hybrid Picea glauca X P. engelmanni, with some pure P. glauca (white spruce) populations in the valley bottoms and a few pure P. engelmanni (Engelmann spruce) at higher elevations. Lodgepole pine (Pinus contorta) is probably the most abundant and widely distributed species, being present as an over-dense subclimax following burning. The spruce occurs chiefly in second-growth, uneven aged stands on glacial till deposits, and excepting the few small areas of virgin timber, Cormack would loosely classify the Eastern Slope forest lands into three categories: recent, intermediate and old burns.[19] Whilst Moss stresses the complexity and instability of both lodgepole pine and spruce fir (Abies lasiocarpa) climaxes,[20] Cormack agrees with Bloomberg[21] in outlining a simple, direct trend from burn to climax.[22] It is estimated that for the

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[18] Rowe, J.S., Forest Regions of Canada, Canada, Dept. of Northern Affairs and National Resources, Forestry Branch, Bulletin No. 23, Ottawa, 1959, p. 36.

[19] Cormack, R.G.H., A Survey of Coniferous Forest Succession in the Eastern Rockies, Forestry Chronicle, Vol. 29, No. 3, Sept.1953, p.219.

[20] Moss, E.H., The Vegetation of Alberta, Botanical Review, Vol. 21, No. 9, Nov. 1955, pp. 493-567.

[21] Bloomberg, W.J., Fire and Spruce, Forestry Chronicle, Vol. 26, No. 2, June 1950, pp. 157-161.

[22] Cormack, op. cit., pp. 218-232 and Spruce-Fir Climax Vegetation in Southwestern Alberta, Forestry Chronicle, Vol.32, 1956, p.348.

three Forest Reserves, at least 516 square miles of the forested area has been burned over at least once by wild fires since 1920, leaving thousands of acres of young pine with virtually no large stands of maturing spruce, the one important commercial forest species (see tables 8 and 9.[23] The frequent, intense fires have led to exposure of mineral soils, and subsequent regeneration in both these and cut-over areas has been quite poor (see Chapter VII). Noting that the rate of succession varies with the abundance and vigour of the climax species, Horton states that succession from fire in the subalpine forest was found to be complete in about three centuries on average.[24]

In his classification of spruce habitat types in the Eastern Slopes area, Ogilvie's six southern associations are distinct from those farther north across the divide between the Highwood and Livingstone Rivers. As to why over one hundred plant species extend into Alberta only in this area, he suggests that the inland extension of maritime conditions is the dominant factor, notably a more pronounced summer-dry winter-wet precipitation regime, slightly higher total precipitation and somewhat milder temperatures.[25] At higher

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[23] Fleming, R.J., A Report on the Forest Inventory for the Forest Survey of Eastern Rockies Forest Conservation Board, Calgary, 1955, p. 5 (unpublished ms.).

[24] Horton, K.W., The Ecology of Lodgepole Pine in Alberta, Canada, Dept. of Northern Affairs and National Resources, Forestry Branch, Forest Research Division, Technical Note No. 45, 1956, p. 28.

[25] Ogilvie, 1962, op. cit., p. 1094 and Spruce Habitat Types in the Eastern Slopes of the Rocky Mountains, Alberta, Canada, Dept. of Northern Affairs and National Resources, Forestry Branch, Forest Research Division, Calgary, 1961, 65 pp. (unpublished interim report).

TABLE 8 - [illegible] (In square miles)

Forest Class	Area
Accessible areas[a]	[illegible]
Softwood, merchantable[b]	237.4
young growth	273.9
Mixedwood, merchantable[c]	4.4
young growth	26.5
Hardwood, merchantable	0.4
young growth	79.9
Total productive	592.5
Total non-productive[d]	232.3
Inaccessible areas	465.2
Softwood, merchantable	11[illegible].4
young growth	140.7
Total productive	254.1
Total non-productive	211.1
TOTAL AREA	1,290.0

Source: Flemming, W.J., A Report on the Forest Inventory for the Forest Survey of Eastern Rocking Forest Conservation Board, Calgary, 1953, Appendix IV. (a) All area under 6,000 feet in elevation. (b) Coniferous stands with an average d.b.h. of 4 inches or better, and an average height of 30 feet or more; 75 per cent or more of the volume is in soft woods. (c) Over 25 per cent of each hardwoods and softwoods. (d) Forest incapable of yielding products other than fuel because of adverse site including slow growing, dwarf or stunted forests, as well as rock areas, marshes, etc.

TABLE 9 - MERCHANTABLE TIMBER BY SPECIES, CROWSNEST FOREST [a]
(Accessible volume in millions of gross cubic feet)

Species	4 - 10 inches	Over 10 inches
Spruce	41.3	196.4
Lodgepole pine	112.6	55.7
Alpine fir	21.3	6.6
Douglas fir	5.7	24.9
Other softwoods	0.9	2.4
Hardwoods [b]	3.6	0.1
Total	185.4	286.1

Source: Fleming, A.J., A Report on the Forest Inventory for the Forest Survey of Eastern Rockies Forest Conservation Board, Calgary, 1955, Appendix IV. (a) Volume figures based on Field Surveys 1949-53. (b) Chiefly poplar. Accessible stands over 6000 feet in elevation might increase the saw timber resource in the whole Forest Reserve by as much as 25 per cent. Classification generally favours over-estimation of the resource.

elevations, towards the tree-line, alpine fir tends to predominate in the open tree layer, together with some spruce, limber pine and alpine larch. Here, the spruce growth is poor, irregularly stocked and shallow rooted. Gradually, the subalpine spruce-fir associations give way to scrubby krummholz and then the little-known alpine tundra, where snowdrifts could be of particular help in watershed management.

Rowe's "Montane Douglas Fir and Lodgepole Pine Section" is located below the subalpine forest in the Porcupine Hills-Waterton Lakes area.[26] Typical of central Montana, it is characterized by the two species mentioned (the former, Pseudotsuga menziesii), and white spruce, with some limber pine (Pinus flexilis) in the foothills and poplar clumps at the wide contact zone with the grassland associations. Moss differentiates a "Boreal-Cordilleran Transition" between the subalpine forest and parkland prairie areas north of the Crowsnest Pass.[27] This foothills association is typified by white spruce and Lodgepole pine among the higher forms, with the latter again the chief pioneering and dominant sub-climax species. The aspen parkland itself consists of a mixture of prairie with aspen groves (Populus tremuloides) which occupy "north and east-facing slopes of valleys, slough depressions, ridges and knolls".[28] Balsam poplar (Populus balsamifera) is more restricted in occurrence, and is usually found in moister situations. All the aspen stands in the area

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[26] Rowe, op. cit., p. 39.

[27] Moss, op. cit.

[28] Idem., The Prairie and Associated Vegetation of Southwestern Alberta, Canadian Journal of Research, C, 22, Ottawa, 1944, p. 23.

are seral, with spruce regeneration chiefly prohibited by burning. Climatic conditions, chiefly moisture deficits, are probably the dominant factors preventing the invasion of adjoining prairie by the aspen consociation.

Drier sites having limited retention storage capacities in the foothills and mountain valleys, together with recently burned-over areas, are covered with grassland associations. Rough fescue (Festuca scabrella) is dominant in the most productive bunchgrass type.[29] Other species in this association are Idaho fescue (F. idahoensis), timber oatgrass (Danthonia intermedia), and Parry's oatgrass (D. parryi), though these may be almost excluded by rough fescue in undisturbed stands. This grass cover is present on the alluvial terraces and on south-facing slopes and foothill ridge tops. It has been reduced to differing conditions by use, and severe depletion is not uncommon. Through over-grazing, more drought resistant, but less palatable, shrubs and herbs increase in importance at the expense of the bunchgrasses, and eventually a thin litter cover gives way to bare ground and soil instability (see Chapter VII). Over large areas, rough fescue has been replaced by speargrasses, oatgrass and June grass (Koeleria cristata), and Hanson wonders whether it might not be better long-term economy to use the range to the point where this replacement is complete.[30]

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[29] Hansoff, A.K., The Range Resource of Alberta Foothills and Mountains, Eastern Rockies Forest Conservation Board, Calgary, 1953, p. 2 (mimeo.).

[30] Ibid., p. 4.

Minor range types in the Forest Reserve are summarized by Hanson.[31] Meadows can be divided into three groups: dry meadows, which frequently occur as glades in the forest, are composed mainly of grasses; the many wet meadows with their sedges and rushes, especially in poorly drained foothill areas; and the limited Alpine meadows containing grasses and sedges. Alpen development has been severely restricted by advanced glaciation and low temperatures. Browse typically consists of a mixture of willow and scrub birch, with intervening sedges and wet meadow grasses. This provides important winter range for big game. The most extensive type in the Reserve, conifer, produces but little grazing. It is chiefly made up of open stands of pine and spruce, and only the more open stands of limber pine, Douglas fir and Lodgepole pine furnish much forage. Bunchgrass amongst the open stands of Douglas fir on the Porcupine Hills often provides excellent grazing. Here, Parry's oatgrass is a very important species "and in the present condition of our range probably produces more forage than any other single species".[32] Frequently, burned-over areas have abundant annual and perennial weeds and some grasses and browse. Aspen poplar dominates the poplar range type which is fairly extensive and quite productive, though many of the species

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[31] Idem., The Grazing Resource of the Rocky Mountain Forest Reserve. Eastern Rockies Forest Conservation Board, Calgary, n.d., pp. 4-5 (mimeo.).

[32] Idem., 1953, op. cit., p. 3.

are only of low palatability. In the parkland, upland grass types may be present, or possibly in mixtures with pine grass (Calamagrostis rubescens) and others of the coniferous type. In all, it is estimated that the Crowsnest Forest Reserve's used range occupies just under half of its total area of 828,740 acres.[33]

SURFICIAL MATERIALS

The important factors determining soil formation in the reserve include parent material, climate, vegetative cover, slope and drainage and the mode to which they have been, or are being put. An intricate variety of zonal and intrazonal soils has resulted, with well-developed zonal soils occurring only in relatively small areas. Under present conditions, especially those of climate and vegetation, podsols tend to be produced in most of the area, with tundra soils at higher elevations and a sequence through grey and brown podsols and grey-brown forest soils to various grassland types in the southern foothills as drought intensities increase. These zonal soils are, however, all to some extent affected by the underlying parent material present.[34] The presence of degraded black soils inside and adjacent to the Reserve probably correlates with the reversion to cooler and moister conditions following a climatic amelioration some two to four thousand years ago.[35]

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[33] Idem., n.d., Op. Cit., p. 3.

[34] Crossley, D.I., The Soils on the Kananaskis Forest Experiment Station in the Subalpine Forest Region in Alberta, Canada, Dept. of Resources and Development, Silvicultural Research Note No. 100, Ottawa, 1951, pp. 9-10.

[35] Mousser, C.J., Postglacial Environments in the Canadian Rocky Mountains, Ecological Monographs, Vol. 26, 1956, p. 297.

Owing probably to the small amount of time available for mature development under any one type of climate and vegetative cover, intrazonal soils are widespread on the glacial drift and fluvial deposits, and also on residual formations over softer foothills rocks. Excessive or inadequate drainage and erosion consequent upon burnings are significant causes of these soil variations. Almost unaltered parent material, the azonal soils cover "bare rock", newly eroded and deposited materials, as well as considerable areas of coarse glacial, colluvial, alluvial and frost-shattered boulder surfaces. The slow breakdown of the hard bedrock and coarse regolith, intense physical weathering, relatively large runoff and stream loads, protection by snow and ice, the widespread moderate to steep slopes and disorganized post-glacial drainage, have all contributed towards the extensive azonal group.

Because of the nature of these soils and the stress here especially upon relationships with watershed hydrology, Laycock's mapping according to a "physiographic classification" serves as a useful base for describing the area's "soils".[36] Its six types based on the physical origins of the surficial materials present, the classification stresses areal patterns of both infiltration and storage characteristics.

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[36] Laycock, A.H., Report of the Soil and Watershed Survey for the Summer of 1952, Eastern Rockies Forest Conservation Board, Calgary, 1953, pp. 4-9. (unpublished ms.).

Areas of bare rock and rocky alpine soils are chiefly located at high elevations, especially in the southern Pre-cambrian area, along most of the Continental Divide and on the ridges of the other front ranges with their widespread bare limestone surfaces. Bedrock exposures occur in non-glaciated areas, in areas eroded by valley glaciers but never drift covered, and where there has been post-glacial removal of drift (mostly in stream valleys). Often the bedrock is only thinly covered with till or scattered erratics. Where present, loose surface materials tend to be coarse and shallow, as erosion has roughly kept pace with weathering. Thus, near the surface there is but little capacity for absorption or retention of water, and vegetation is either poor or absent. As noted above, precipitation on the western ranges is relatively high, while evapotranspiration losses are low owing to the lack of plant growth and low temperatures. Consequently, yields of runoff from snowmelt and rainfall may be as high as sixty inches and not delayed later than spring or very early summer. Typical back-range water-balance equations (precipitation equals evapotranspiration plus streamflow plus/minus storage change) might be:
November to May: 50 = 2 + 3 + 45; June and July: 6 = 4 + 44 = 42;
August to October: 10 = 3 + 1[illegible] - 3. (All in inches).
Severe physical weathering in parts of the watershed has increased detention storage potentials or allowed movement of water to porous or fractured bedrock. Where there is some vegetative cover development, soils are forming, snow drifting has been encouraged and snowmelt retarded. This represents a very good form of surface detention storage.

More widespread than these are the postglacial residual soils which have some degree of profile development. Found in foothill rather than mountain areas, they occupy slopes "that are not so steep that the natural rate of erosion exceeds soil development from parent rock or so shallow that transported material has been deposited and retained upon them".[37] Although there is some intrazonal and zonal profile development, the group is chiefly azonal, but variations in depth, texture, drainage qualities and watershed values limit meaningful generalizations.

Areas underlain by sandstones on the foothill ridges and the limited areas of suitable shales in the valleys and on lower slopes have deeper, finer textured soils than have the less easily eroded materials such as limestone and igneous rocks. Vegetation has important effects, especially upon soil structure and texture in the intrazonal and zonal soil groups. Podzolic soils have higher infiltration and lower retention storage capacities than have the grassland soils with their finer materials and greater erosion hazard.

Water yields are much smaller in these lower mountain and foothill areas than in the back ranges described above, though regimes tend to be better. Consequent chiefly upon differences in soil moisture storage, yields vary from eighty-five to twenty per cent between the coarse residual deposits of the front range - foothills margin and the fine, deep materials in the outer foothills. Unfortunately for some

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[37] Ibid., p. 5.

aspects of past multiple-use, many of the residual slopes are subject to an excess of erosion over soil development under all but optimum vegetative cover.

High detention storage capacities and general instability characterize poorly-sorted colluvial soils which are found at the base of steep, bare slopes whose run-off they impede for summer release. Predominantly made up of limestone, they are often inter-mixed with glacial and alluvial deposits in their coarser downslope portions. Usually they have very little surface soil material, low evapotranspiration losses and variable water yields. They are notably found downslope from bare rock and rocky alpine soils in the Boundary and Livingstone Ranges, and also on relatively large areas of the Castle and adjacent watersheds.

Amongst the best for forest growth and watershed properties, glacial soils, other than those of glacio-fluvial origin, are chiefly developed on coarse glacial tills, though morainic areas along and across valleys and below cirques are locally important in increasing storage potentials in the mountains. Much of the reserve is covered with varying thicknesses of this unstratified mixture, but it has already been eroded from the steeper slopes. Forest growth upon intrazonal podsolic soils developed on drift improves infiltration and storage capacities, but water yields are reduced through interception and transpiration losses. Moderate yields of good quality water of favourable regime derive from the extensive back-range drift basins.

Alluvial and glaciofluvial soils are grouped together owing

to their similar properties, but are very variable in their depth and textural qualities. Present notably in the less steep lower valleys as series of silt-covered terraces such as those of the Livingstone and lower Castle Rivers, they contribute significant storage for runoff from higher slopes, even though infiltration capacities tend to be somewhat low. Advantages from detention of water for dry season runoff are often offset by phreatophytic losses. These soils have been particularly susceptible to abuse through overgrazing, which has limited use of the high detention storage potentials of the coarser subsurface materials, and provoked increased quantities and rates of surface runoff. Again, water yields are quite varied, but tend to be lower than those from adjacent slopes.

Poor drainage marks off the bog and marshland soils which occur in a wide variety of locations. They are of limited extent, and are typically found at all elevations on relatively flat terrain where there is an impermeable subsoil or a high water table present. Palustrine deposits and gleying commonly occur. Their value in watersheds is small owing to small unused storage capacities, low infiltration rates and large evapotranspiration losses which reduce yields in dry years in all but the higher areas. Typical sites are in low-lying floodplains such as that of the east Branch of the Castle River when ponding by alluvial fans is coupled with a flat valley bottom; in clay areas on drift such as parts of the Beaverdam Creek watershed; on shallow residual slopes over shales; on low terraces; for example along the northwest branch of the Oldman River, and on saddles of some divides, such as in Allison Pass.

CHAPTER V

AREAL STANDARDIZATION VARIATIONS ON THE EASTERN SLOPES

As was shown above, there are distinct areal differences in the water balance on watersheds of the eastern slopes in southwestern Alberta. On a local level, these relate particularly to the distribution of surficial materials and plant cover. However, by applying the relationships introduced in Chapter III and the approximate patterns of precipitation, soil and vegetation, it is possible to use evapotranspiration estimates and available streamflow records to obtain a general impression of overall water yield variations in the area. All the reservations made in using this approach must be recalled, and it should be stressed that, pending intensive surveys and research, only approximate patterns can be evaluated, and then in qualitative rather than quantitative terms.

Using this method, Laycock has mapped seventeen "precipitation and water yield regions" in the mountains and foothills area of the Saskatchewan River basin.[1] Seven of these are located south of divide which separates the Milk-Waterton and Oldman drainages of the Bow River system. North of the International Border, which merits its own "Southern Mountain and Foothill Region", the Crowsnest Forest contains, from west to east, the Western and Eastern Ranges

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[1] Laycock, A. H., Precipitation and Streamflow in the Mountain and Foothills Region of the Saskatchewan River Basin, Prairie Provinces Water Board, Report No. 6, Regina, 1957, fig. 1. (Mimeo)

and Valleys, the eastern slope of the Front Range, the Low Foothills and Plains and the Porcupine Hills. The most significant boundary is that drawn along the crest of the easternmost front range, parts of which rise above seven thousand feet above sea-level, whilst that between the two range and valley sections lies along one of the intermediary north-south ranges north of the Pre-Cambrian area. In the east, the reserve boundary, approximately following the five thousand foot contour, denotes the western extent of the low foothills and plains.

Using these divisions as a basis, some salient features of differences in water resource patterns on the eastern slopes deserve attention. The southern mountain ranges and the western ranges and valleys contribute large discharges to the Saskatchewan system, chiefly from their high winter snowfall. The former receives relatively high spring rainfall intensities owing to its exposure to the east. Flow variations from year to year are only moderate, and there is a tendency toward concentration in summer time. In contrast, the eastern section of the ranges and valleys includes quite dry valley areas where summer moisture deficits are common and snowmelt particularly early. Here, contributions to streamflow come chiefly from the snowmelt and rainstorms of the area's higher mountainous portions. In general, peak streamflow is earlier, more variable and more concentrated in spring and summer than in the western subdivisions.

On the eastern slope of the front range and in the Porcupine Hills, streamflow is even more restricted to the earlier snowmelt and important spring rainy periods. A comparison of discharge measurements from the stream gauges along the Waterton River illustrates

tria difference reasonably well. Stre flow deriving from the area above Waterton Lake is less concentrated in one part of the year than that measured below Lower Waterton Lake and at Standoff, both of which include front range and foothills runoff. Moisture deficits after July are reflected by low streamflows in late summer and autumn. Flow varies appreciably both seasonally and annually, chiefly on account of the highly variable patterns of precipitation and evapotranspiration and the relation between them. Baseflows of streams are relatively less important components in the discharge hydrographs.

Precipitation intensities decrease onto the plains, deficits increase and there is a greater frequency of intense summer droughts. Water yields are again highly erratic, and flash-flow accounts for much of the runoff. Comparison of the discharge of Willow Creek at Claresholm and Nolan illustrates the difference. Extreme flood-flows of short duration occur in some years, and actual time of peak flow tends to be closely related to the annual discharge. It varies between April and June. The total March-October discharge recorded at Nolan for the period 1942-61 varied from a high of 336,200 acre-feet in 1953 to a low of 27,390 acre-feet in 1961.

As a refinement to these observations, areal differences in hydrologic characteristics may be examined by subjecting one significant aspect of streamflow, peak discharges, to an analysis regarding both their magnitude and frequency. Techniques have been developed in this direction for the prediction of both peak and low flows along gauged and ungauged streams.[2] Flood frequency curves were fitted

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[2] Benson, M. A., Evolution of methods of evaluating the occurrence of floods, United States Geological Survey, Water-Supply Paper No. 1580-A, 1962, 30 pp.

by eye to annual peak daily discharges[3], plotted on log X probability paper using the method summarized by Dalrymple.[4] Adjusted plotting positions, necessary owing to the occurrence of short, discontinuous records at some gauges, were taken from I. J. H. R. data.[5] Median floods[6] so evaluated for the eighteen stations listed in Table 10 could then be used relative to quantitative watershed variables such as drainage area and slope factors[7], and also to the one per cent flood in the definition of areas having similar flood characteristics. Attempts at multiple graphical correlation with basin features were so severely hampered by lack of data that no more than trivial conclusions could be adduced.

Three features of the individual Q_{max} frequency curves were then examined: the median flood itself, the slope of the curve and any significant curvature present. The magnitude of the median flood is influenced by many factors, both physiographic and climatic, and can either be correlated with these individually, or with a combination of these, such as the basin lag or mean annual runoff. This last

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[3] Gumbel, E. J., Annual floods and the partial-duration series, Trans. Amer. Geophys. Union, Vol. 30, 1949, pp. 879-886.

[4] Dalrymple, T., Flood-frequency analysis, United States Geological Survey, Water-Supply Paper No. 1543-A, 1960, pp. 1-47.

[5] Durrant, E. F. and D. E. Blackwell, The Magnitude and Frequency of Floods in Alberta, Saskatchewan and Manitoba, Canada, Dept. of Agriculture, P. F. R. A., Hydrology Division, 1961, pp. 26-41.

[6] Blench suggests that taking the mean or median discharge might be as good as taking the 1 in 2.33 year discharge, which is based on the assumption that the data must follow a special statistical laws. (Canada, Dept. of Northern Affairs and National Resources, Water Resources Branch, Proc. Symposium No. 1, Spillway Design Floods, Ottawa, 1959, Ottawa, 1961, p. 150.)

[7] Practical methods of computing most of these are given in Gumbel, E. J., Hydrologic Characteristics of Mining Basins, United States Geological Survey, Water-Supply Paper No. 960-B, 1949, pp. 149-157.

TABLE 10 - SELECTED FLOOD-DISCHARGE DATA FOR STATIONS IN THE OLDMAN RIVER BASIN

River	Station	Drainage area (in square miles) Dry	Gross	Years of Record	Average flow c.f.s.	Maximum flood (c.f.s.)	Ratio flood / Median flood	Ratio flood / $A^{0.8}$
Belly	International Boundary	74	75	14	260	1300	2.2	41.1
Belly	Mountain View	119	121	49	315	1750	2.4	37.7
Belly	Standoff	356	477	28	380	2400	2.9	17.3
Belly, N. Branch	International Boundary	...	1	7	34	180	2.2	20.6
Boundary Ck.	International Boundary	21	21	11	77	410	2.0	30.0
Castle	Cowley	412	435	21	625	4400	3.6	34.1
Crowsnest	Frank	153	163	16	185	1000	4.0	17.1
Crowsnest	Lundbreck	247	268	22	250	1200	4.0	13.8
Lee Ck.	Carleton	112	112	42	62	500	10.8	11.1
Oldman	Gap	432	454	6	415	3400	4.7	25.4
Oldman	Cowley	722	750	20	560	3600	3.6	18.5
Oldman	Macleod	2100	2200	35	1300	9000	3.7	13.9
Old Man Current Ck.	Many Glacier	32	32	49	151	940	2.0	60.3
Waterton	International Boundary	60	61	1	275	1900	1.8	79.9
Waterton	Waterton Mills	230	238	33	670	4000	2.5	50.3
Waterton	Standoff	350	695	41	940	5200	2.3	20.3
Willow Ck.	Churchbridge	430	462	17	145	1000	9.0	7.6
Willow Ck.	Nolan	746	1010	45	175	1500	8.0	6.5

Source: Canada, Dept. of Northern Affairs and National Resources, (etc), Water Resources Branch, Water Resources Papers, Arctic and Western Prairie Basins, Ottawa. (a) Current, ... and ... Blackwell, The magnitude and frequency of floods in Alberta, Saskatchewan and Manitoba, Canada, Dept. of Agric., ... Regina, 1961, pp. 24-25.

given the order of both the precipitation available and the runoff producing characteristics of the individual basin concerned, and was found to give an excellent correlation with the median flood. It is to be expected that under dry climatic conditions the median floods will be low, and vice versa in more humid areas, and this is shown by comparing the average daily flows on median floods with drainage areas. On a square mile basis, these respectively were, for example, 3/4 and 20 c.f.s. for Boundary Creek at the International Boundary and 0.5 and 4.3 c.f.s. for Lee Creek at Cardston. Correlation between the median (or mean) annual flood and the drainage area does not seem to be as good as Durrant and Blackwell seem to think, though their degree of generalization in discussing a much larger area warrants allowance for a greater variation.[8] There is, however, a trend in the data towards three groupings when plotted on log. X log. paper ($Q_{max} = 44A^{0.95}$, $Q_{max} = 68A^{0.9}$ and $Q_{max} = 110A^{0.9}$), i.e. stations on and north of the Crowsnest River, those to the south, and those on streams arising upon the eastern slope of the easternmost front range.

The difference between the first two of these groupings reflects the influence of the embayment of lower precipitation and higher potential evapotranspiration found both in the Crowsnest Pass area and in the middle Oldman-lower Livingstone valleys, a phenomenon not found in the narrower southern section. Thus, at the western boundary of the low foothills and plains, the Oldman and Waterton

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[8] Durrant and Blackwell, op. cit., p. 7, using the "mean annual flood" of 2.33 year recurrence interval, found that correlation between it and effective drainage area was so good within their regional boundaries that "investigation of other factors hardly seemed profitable".

rivers respectively have average annual daily flows of 0.9 and 2.8 c.f.s. per square mile, the latter having roughly half the former's drainage area. This provides an added justification for separating the northern of the two structural units lying west of the foothills into two parts, as was noted above.

Of more interest here is the pattern of slope of the frequency curves, and this can be expressed as a non-dimensional value by using the ratio between the median and the one per cent flood. Although chance is the main cause of the variability of annual peak discharges, drainage basin characteristics also play a considerable part. The range of this numerical parameter, which was found to be inversely related to $\frac{\text{median flood}}{(\text{drainage area})^{0.8}}$ given relatively constant basin qualities, is from 1.8 on the Waterton River at the International boundary to 9.0 at Clarresholm on Willow Creek, with again the threefold division being evident. Theoretically, the ratio should decrease downstream on a particular river owing to the lack of correlation between peak flows on streams contributing to the increased drainage.[9] Whilst this holds true for the Oldman River between the Dap and Lowley and also Willow Creek, both the Waterton and Belly Rivers exhibit increasing variability of annual Q_{max} with distance downstream, as also does, though to a lesser degree, the Oldman between Lowley and Fort Macleod. The Waterton, for example, has a ratio of 1.8 at the International boundary, 2.5 at Waterton Mills and 3.3 at Standoff. This is presumably due to the influence of the same causal factors which produce the steep curves for Willow

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[9] Fuller, W., 100 Frequency Curves of North American Rivers, Proc. Amer. Soc. of Civil Engineers, Vol. 83, No. HY5, Oct., 1957, 31 pp.

and Lee Creeks (respectively, 9.0 at Clarenholm and 10.8 at Cardston), i.e. eliminate, also, infiltration and storage characteristics.

When the infiltration capacity is exceptionally low, or storage depressions full, the peak flows will be roughly proportional to the size of rainstorms, and the runoff coefficient will approach one hundred per cent for heavy rains of short duration. In contrast, where infiltration conditions are better, storage available and rains are such that little water will reach streams, the coefficient will be far smaller. Peak flows should increase quicker than rainstorm size, so that the ratio itself should be greater. Although there are significant local variations in the low foothills and plains, where are quite shallow and consider ble amounts of surface runoff never reach major streams. Closely connected with this last effect, the main cause stems from the variability of precipitation incident upon the western slope of the front range, the foothills and adjacent plains, as well as the point that were storms of equal magnitude to occur in the whole area, the effects upon relatively wet and dry areas would be to produce a steeper curve in the latter. Infrequent series of intense rainstorms of long duration centred especially on the foothills, and with runoff coefficients increased owing to removal of the vegetative cover through fire and use, have caused record floods such as those of June-July 1915, June 1923 and June 1953, when stream channels were unable to accommodate the flow. Curvature in the upper portion of many of the frequency curves may be caused by the short-term nature of the data used in their calculation. Alternatively, it may derive from the use of statistically non-homogeneous populations.

The frequency [illegible] lends support to the breakdown into distinctive recreation and water-yield areas, especially regarding the differences astride the eastern front range. It should provide a fundamental division in the study and management of the area's streamflow resources.

CHAPTER VI

RUNOFF FROM THE ALBERTA PLAINS

About two thirds of the area drained by the Oldman River and its tributaries lies outside the mountain and foothill areas described above. Following the examination of streamflow patterns in that area, a cursory discussion of water surplus variations on the Alberta Plains serves to emphasize the overall contrasts present within the basin as a whole. Despite its usually small annual streamflow contribution, amounting in a dry year to well under one quarter inch yield, the plains area adds significantly to flood discharges in some seasons. The importance of the local runoff which does not flow out of the area must not be underestimated, and it has been suggested that "local runoff (including that reaching streams) in the settled portions of the Prairies is on the average at least four times as great as the volume of water in the South Saskatchewan River that is available for irrigation in Saskatchewan and Alberta." (italics mine).[1] In the Oldman sub-basin itself, however, local runoff is relatively of less importance. The economic value of these supplies on the plains deserves note, even though most of the larger users of water in the basin rely upon the greater, more dependable flows deriving from the Eastern Slopes.

As was noted in Chapter IV, the land lying to the east of the "Disturbed Belt" consists of a broad, stable depositional zone with two

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[1] Laycock, A.H., Local water supplies in the prairies, Edmonton, 1959, p. 5. (mimeo).

major structural components, namely the Sweetgrass anticlinorial Arch and the Alberta Syncline. Both of these have northwesterly trending axes paralleling the strike of the front ranges. Tertiary sedimentary deposits have been preserved within the Syncline, the rest of the basin in its plains section being occupied by Cretaceous rocks, a complex series of interbedded sandstones and shales. The Lower Cretaceous Eagle Formation, which underlies much of the eastern portion of the area, has as its basal component the Milk River Sandstone, whose fan-like structure is caused by diverging axes within the Sweetgrass Arch. This forms the largest sandstone aquifer in Alberta, and Meyboom estimates its annual production at a meagre 950 acre-feet.[2] These diminishing supplies are chiefly used for domestic purposes and livestock watering in the area of internal drainage between the Lower Oldman and the Milk River. Its poor quality renders it unfit for use in irrigation or industry. Although more dependable than supplies from surficial deposits (e.g. the marginal moraines, outwash plains, sand plains and drift-filled buried channels), bedrock groundwater is often dependent upon these overlying materials, tends to be limited in amount, subject to little movement, costly to pump, and often saline.[3]

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[2] Meyboom, P., Geology and Groundwater Resources of the Milk River Sandstone in Southern Alberta, Research Council of Alberta, Memoir No. 2, Edmonton, 1960, p. 78.

[3] Vide Foster, J.W., and R.N. Harvolden, A General Outline of Groundwater Conditions in the Alberta Plains Region, Research Council of Alberta, Geology Division, Preliminary Report No. 58-1, Edmonton, 1958, 35 pp. and Ledrew, E.J., and J.F. Jones, A Regional Picture of the Groundwater Chemistry in Particular Aquifers of the Western Plains. Third Canadian Hydrology Symposium, Calgary, Nov. 1962, Contribution No. 184, 40 pp. (mimeo to be published).

Most of the basin has been covered with Pleistocene and Recent materials as a result of glaciation and subsequent depositional processes. Underlying Tertiary and Cretaceous formations outcrop in some of the ice-marginal drainage channels which cut across the rolling, northeasterly sloping surface. Bedrock exposures are not, however, very common in the area. North of the St. Mary Reservoir in the Blood Indian Reserve is a particularly extensive area of bedrock which is only thinly overlain with till, while rock outcrops occur on the Milk River Ridge, an arcuate upland north of the Milk River between Milk River townsite and Whiskey Gap. The steep-walled post-glacial valleys now occupied by the major streams comprise the major active dissection in this badly disorganized drainage area.

Physiographically, the land surface is characterized by an intricate assemblage of surficial deposits, which also dominate the water relationships of the area. Although Wisconsin Laurentide ground moraine is the most widespread feature, a variety of glacial, glaciofluvial, alluvial and aeolian deposits is present, each having its own peculiar slope, infiltration and storage properties.

Areal differences in the climatic and vegetative variables between the foothills and the centre of the Palliser Triangle are less dramatic than those in more westerly locations, and are summarized in Chapter IV. Average annual precipitation totals vary from about twenty inches at Lyndon, Pincher Creek and Cardston in the west to about thirteen inches at the Oldman's confluence with the Bow. The considerable annual and seasonal variations in amount can be conveniently discussed in association with potential evapotranspiration estimates

relative to water surplus patterns. Between the same locations, average annual potential evapotranspiration ranges from eighteen inches in the west to almost twenty-four inches in the east, so that, on average, precipitation is balanced by evapotranspiration losses. Omitting many variables and taking water yield simply as precipitation minus actual evapotranspiration, annual surpluses occur more frequently with distance westwards across the basin (calculating the data on a monthly basis). The variability from year to year is illustrated by the discharges of such streams as Ralph and Pothole Creeks. In the period March-October 1949, for example, Ralph Creek's total flow amounted to 4,350 acre-feet from the 66 square miles above Kimball. For the same period in 1953, it was 23,020 acre-feet. Further, maximum daily discharges recorded were respectively 57 and 962 c.f.s. for the two years. In general, runoff is dependent upon snowmelt, exceptional rains and precipitation upon areas of limited storage capacity. Surpluses thus tend to be concentrated at times of late winter snowfall and early spring rainfall, with moisture deficits prominent in late summertime. Low baseflows accentuate this marked peaking of streamflow discharges (see Appendix III).

Unless infiltration rates are insufficiently large for a given precipitation intensity or rate of snowmelt, precipitation will go to fill moisture storage capacities before any significant runoff can occur. With assumptions for storage and runoff opportunities, the effects of the plant cover and local precipitation variations, estimates of water yields can be made for individual areas. As the various landform types which make up the surface of the basin possess

relatively homogeneous watershed characteristics, some meaningful generalizations about runoff patterns can be made on the basis of their distribution.

To illustrate the range of variation in the water balance, two dissimilar areas can be compared, both having comparable precipitation and potential evapotranspiration characteristics. Hypothetical equations are given in Table 11 for an outwash plain paralleling the Oldman River in the northern part of the Peigan Indian Reserve and also for a part of the lacustrine plain which extends westwards from Stirling to the St. Mary River.

With many features common also to the widespread till plains, the lacustrine area of fine, clayey soils possesses a large retention storage capacity into which water moves quite slowly owing to low infiltration and percolation rates. Water is unable to run off and augment streamflow because of shallow slopes and lack of an organized drainage network. (Postglacial water supplies have been insufficient to dissect the landscape). Consequently, maximum opportunity is provided for infiltration and loss through evaporation. As for the water which does penetrate the surface, little succeeds in reaching below root depth. Even assuming a twelve-inch moisture storage capacity for the whole basin, average annual deficits range from one inch adjacent to the foothills to over ten inches at Bow Island.[4] The greater slope found in till plains stimulates greater concentration of runoff into depressions.

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[4] Laycock, A.H., Drought Patterns in the Canadian Prairies, Extract of Publication No. 52, International Association of Scientific Hydrology, Helsinki, 1960, Louvain, 1960, fig. 11, p. 42.

TABLE 11 - [illegible] WATER-BALANCE EQUATIONS
(in inches)

Period	McMahon reserve: ppt. = et. + str. + st.ch.[a]	Stirling: ppt. = et. + str. + st.ch.
Average year	18 = 13 + 5 (22 - 9)[b]	16 = 15 + 1 (22 - 7)
Year	9 = 12 - 0 - 3 (21 - 9)	8 = 13 + 0 - 5 (19 - 6)
Autumn, winter and spring	9 = 2 + 5 + 2 (9 - 0)	9 = 2 + 1 + 5 (9 - 1)

(a) Abbreviations used: ppt. precipitation; et. evapotranspiration; str. streamflow; st.ch. storage change. (b) Potential evapotranspiration minus deficit.

In contrast, the sandy outwash, with its coarse textured soils, allows extremely rapid infiltration of moisture to recharge its limited retention storage capacity. Much of it percolates beyond root depth to augment groundwater supplies or, eventually streamflow. Aeolian sand plains, such as in the Pearce area, have somewhat similar qualities, but tend to be underlain with relatively impermeable clays which are responsible for the numerous sloughs characteristic of such deposits. In all, sandy surface materials are relatively limited in occurrence, and some, for example in the area south of Macleod, exhibit numerous blow-outs as a result of past misuse.

The extensive areas of hummocky moraine, with their steep slopes and high water tables, have a somewhat intermediate position relative to the other two groups in that whilst much water is lost by evaporation, the amount passing into streamflow and groundwater reserves is higher than in lacustrine or till plains. Hummocky moraine is present in a broad, discontinuous band between the southern margin of the Porcupine Hills and the International Boundary east from the St. Mary River.

Streamflow contributions from the plains are, then, generally small and exceptionally variable. Runoff derives from snowmelt in early spring, though discharge from heavy rains in late spring may be greater in some years. Many of the local depressions are usually without external drainage, so that while local runoff may be significant, only in particularly wet years after prolonged rainstorms will these areas contribute to mainstream flood flows, as occurred, for example, in June 1953. As an indication of this difference, the effective drainage areas of Pothole Creek above Magrath and Kolyk Creek above Kimball are

both approximately sixty-five per cent of their respective gross drainage areas.[5] Annual surpluses exceeding eight inches tend to be associated with severe erosion and flood damage, owing partly to lack of soil protection from an effective vegetative cover. High River, located in the west near the head of the Little Bow, had over eight inches of water surplus in twelve per cent of the years of the period 1921-50, but frequencies of this magnitude decrease markedly with distance eastwards. Assuming a comparable storage capacity of four inches, the corresponding figure for Fort Macleod is three per cent. Water yields for the period October 1952 to September 1953, a particularly wet year, reached twenty inches roughly along the Reserve's and National Park's eastern boundaries, decreasing rapidly to five inches along the Blacktail-Standoff-Immigrant Gap line. Most years have only small to moderate surpluses, with but minor contributions to streamflow. Average yields exceeding two inches occur only in a small portion of the western part of the plains.

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[5] Durrant, T.F., and S.R. Blackwell, The Magnitude and Frequency of Floods in Alberta, Saskatchewan and Manitoba, Canada, Dept. of Agriculture, U.S.A., Hydrology Division, Regina, 1961, p. 25 and vide Chapter IV, footnote 1.

CHAPTER VII

THE [illegible] CONSERVATION BOARD

A brief resume of land use on the western slopes and adjacent plains in the period prior to the establishment of the Eastern Rockies Forest Conservation Board provides useful perspective to a discussion of the aims and achievements of that body.

[illegible] 1947

Lecount[1] quotes a report by Mr. George Lecount, made in 1874, noting "a band of cattle in the vicinity of the line south of Wood Mountain (in Saskatchewan) which had strayed from one of the United States' forts to the south", and within a decade ranchers from the south were playing an important role in the northward expansion of the existing cattle range area into Canada. Following the establishment of Fort Macleod in 1874 and the Blackfoot Crossing Treaty of 1875, together with the severe depletion of buffalo herds, the Government had to face the task of providing food for the Indian population, now confined inside reserves.

In an attempt to stimulate beef production, a thousand head of breeding cattle were brought over the border in 1879, and soon capital began to flow in from Eastern Canada, the United States and

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[1] Lecount, C., Manitou and the Great North West, London, 1883. John Lecount was an explorer and botanist to the Canadian Government's expeditions surveying the territory in preparation for the construction of the C. P. R.

urope to develop the livestock industry of outh-western lberta.[2] razin leases were made available to anyone interested thro legislation enacted in 1876, when the terms of the ori inal Land ct (1872) were broadened. y 1881, regulations provided for the lease of as much as 100,000 acres for twenty-one years at a rental of one cent per acre and subject to a requirement as to the stocking of the leasehold".[3] he grazing resources of the outer foothills and adjacent plains in the basin were found to be particularly attractive, so the better grasslands were quickly claimed or leased, though the actual ranching units were much smaller than those established further east.[4] orse and ee ranching, though recent, never reached the proportions of the cattle industry.

Outside markets became accessible to the ranchers with the construction of railways, first the trans-continental . . . line through to algary in 1883, and then important branch lines a few years later. his, together with the growth of mining settlements in the Crowsnest ass area, led to a rapid exploitation of available timber supplies, which were also in heavy demand on the plains.

n act of 1906 set aside a large area in the foothills and mountains which was considered unsuitable for agriculture as a

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[2] urchie, . ., _ricultural ro ress on the rairie rontier_. acmillan, oronto, 1936, pp. 94-95.

[3] _Ibid_., p. 94.

[4] ameron, . . and orterson, L., _rairie ro ress_. Dent, oronto, 19 , p. 66.

forest reserve, but attempts at regulating land-use there were not begun until eight years later. Under the 1911 Forest Reserve and Parks Act, administration of the eastern slopes north of Waterton National Park was vested in the Federal Forestry Branch, whilst the Dominion's other forest lands were unfortunately transferred to the Timber and Grazing Branch.[5] With control by this agency, boundaries and grazing regulations were quickly set up for the Rocky Mountain Forest Reserve as a whole, to the encouragement of very heavy grazing activities. This policy was pursued ostensibly to keep the grass cover as short as possible, and therefore reduce fire hazards.

Ranchers continued to move westwards into the mountains in their search for summer forage, and in many parts of the reserve the highest grazing intensities were achieved during the second decade of this century. Decline stemmed from depletion of the better grasslands, roughly at the same time as there was a general decline of ranching in Alberta. In part this was a result of the drastic reduction by settlement of the open range,[6] though the severe winter of 1919-20 was a contributing cause. In much of the area the vegetative resources were quite seriously mined in a short-run sense and were exploited after payment of only nominal fees, without adequate provision for conservation. Also present, but of

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[5] Martin, W., Dominion Lands Policy, Macmillan, Toronto, 1938, pp. 447-450.

[6] Ibid., pp. 432-443.

relatively little importance, were recreational, hunting and fishing activities.

The Crowsnest Forest Reserve, which retains its original boundaries, extends from just beyond the limits of moderately widespread settlement in south-western Alberta to the Continental Divide. It includes most of the predominantly forested areas of the foothills and mountains, leaving a free corridor through to the Crowsnest Pass. Under the 1911 statute, "the regulation of timber on the forest reserves of Dominion lands was attempted on principles of scientific forestry"[7], but little control was exercised in this particular forest. Responsibility for administering the Reserve was relinquished by the Dominion in 1930, when the Province of Alberta assumed control. The Provincial Forest Service became a fee-collecting and servicing organization for the "orderly development" of the area's resources, and charges levied for resource utilization were used to pay for services such as limited fire protection, roads, bridges and telephone lines. Fire continued to be a major problem[8], whilst resource deterioration, poor market conditions and the economic stringency of the depression led to reduced usage of the area. Subsequent disruption in the war years hampered any attempt at serious rehabilitation.

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[7] Vide Annual Reports, Dominion Forest Service 1927, Ottawa, 1929.

[8] A brief by the Canadian Institute of Forestry (1954) examining the Alberta Forest Service's record during the period 1940-49 presented a very unfavourable view of the forest fire situation in Alberta, though this picture was challenged in 1956 by the then Director of Forestry in Alberta in a response to the Institute.

about one-sixth the size of the Crowsnest Forest Reserve, Waterton National Park now covers some 203 square miles. It was originally reserved under an order in council of May, 1895, and for a period following the 1911 Act mentioned above had its area cut to only thirteen square miles. In a restatement of earlier legislation, the National Parks Act of 1930 (still the legal basis of national parks administration in Canada), the principle of protection was strengthened:

> 4. The parks are hereby dedicated to the people of Canada for their benefit, education and enjoyment, and such parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations.[9]

The relationship between this concept, conditions in the Park and watershed management are discussed below in Chapter IV.

In 1937, discussions began between the Provincial and Federal governments regarding the possibility of a joint approach towards remedying problems of great concern not only to Alberta, but also to the other Prairie Provinces. Especially was this need apparent after 1935, when the Prairie Farm Rehabilitation Administration was set up,[10] and also in view of the enormous capital investment in irrigation projects which are dependent upon stream-flow originating on the watershed lands. The chief problem from the

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[9] The National Parks Act, 1930, George V, Chap. 33, s. 4.

[10] Under the Prairie Farm Rehabilitation Act, federal funds were made available and used to cover the costs of rehabilitation activities, essential in placing Prairie agriculture on a sound, permanent base. Vide L. H. Newman - The Story of Conservation in Canada, Dept. of Agriculture, Publication No. 1135, Oct. 1961, pp. 1-16.

federal standpoint was the destruction of the forest cover and its regulating effects on the water supply through fire and the ensuing lack of effective regeneration. This was felt to be contributing to erratic streamflow regimes, erosion and silting, deterioration of recreational land-uses and other retrogressive effects. After protracted deliberation, joint legislative measures resulted in a twenty-five year agreement between the two governments. The Eastern Ontario Forest Conservation Board was set up as an independent public authority under the management of one provincial and two other members with two-year terms.[11]

The Act "respecting the protection and conservation of the forests on the eastern slopes of the Ottawa watershed" was assented to on July 17, 1947.[12] In it the Board's "purposes or objectives" were defined as being

> a. to construct, operate and maintain and to supervise the construction, operation and maintenance of projects and facilities required for the conservation of the forests and the protection of the waterflow in the area;
>
> b. to protect the forests in the area from fire, insects, disease and other damage; and
>
> c. to conserve, develop, maintain and manage the forests in the area with a view to obtaining the greatest possible flow of water in the Ottawa River and its tributaries.[13]

Under the terms of agreement (June 19, 1947), for the purposes of effectuating forest objectives, the Board was authorized

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[11] On the subsequent thirteen-year period, the Board was changed to comprise two provincial members and one federal member.

[12] Statutes of Ontario, 1947, p. 311.

[13] Ibid., p. 312.

a. to make plans along the line of modern forestry practice from time to time for

i the forest inventory of said area;

ii the location, construction and maintenance of roads, trails, lookouts, telephone, communication systems and other forest improvements required by modern forest practice for forest protection and forest management of said area;

iii forest protection and management of said area, including plans for clearing the said area or any part thereof in case of emergency;

iv research in silviculture and scientific investigations;

v reforestation of said area;

b. to supervise and enforce, as circumstances may permit, execution of such plans...;

c. to make arrangements with the Dominion, the Province or other agencies for the undertaking of research and other scientific investigations for the obtaining of aerial photographs, the making of control surveys and the preparation of maps and plans.[14]

To carry out these charges, the Board was to be financed jointly by the federal and provincial governments to an annual total of $250,000, some $125,000 of this being contributed by the Province, which would continue to receive revenues from timber sales, grazing and other resources up to that amount. In addition, a capital sum of $6,000,000 was to be provided by the Dominion during the first six years of the agreement:

> for the location and construction of forest improvements, the making of a forest inventory, the reforestation of the said area and such other works as it (the Board) may consider necessary.[15]

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[14] Ibid., p. 116

[15] Loc. cit.

Thus it was intended not only to reforest denuded areas, but also to expand fire protection, develop communications, provide additional equipment and personnel, to overcome the arrears of maintenance during the war years. The provisions of Alberta Timber Act, inter alia,

> a. to carry out, under the direction of the Board -
>
> i the programme of works prescribed each year for the purposes of the Agreement;
>
> ii the programme of forest development laid down by the Board;
>
> b. to adopt, with the approval of the Board, and carry out a policy of reinstatement with regard to its undertakings in such areas as will reduce to a minimum any danger from fire during any interruption of the programme of the Board;
>
> c. not to grant certain timber or surface rights which might injuriously affect the carrying out of the purposes of the Agreement.[16]

The provisions of the Act allow for a broad coverage of interpretation by the Board. However, it is clear that the term conservation as primarily concerned with forestry, one Board member stated that its duty is to provide flow of water, particularly summer flow, for the Bow River irrigation country in one of the most important tools to be used in achieving that end" (Hartley-Pine).[17] The third purpose or objective was accepted as the guiding clause in the Board's terms of reference, and the unofficially phrased "pre-test possible flow" was interpreted as meaning the "greatest possible regulated flow"

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[16] Ibid., p. 26-27.

[17] Hartley, R., Water conservation in relation to the best uses of the Bow Country Mountains, Forest Conservation, vol. 51, series 3, section 4, June, 1957, pp. 4 and 26.

taking account of undesirable flow-regimes, erosion, inferior water quality, changing demands and other uses of the forest reserves. Regarding this last, the act fails to incorporate a multiple-use concept of resource development, but, present and potential importance of other than watershed uses warrants development and adjustment of some of these to a degree where they do not seriously conflict with watershed values.

VI

"We feel that our first duty is to prevent forest fires."[18] "The greatest threat to good management is fire."[19] Such comments from eastern Alberta forest conservation board personnel emphasize that body's considerable achievement since its inception. Together with an intensified and uninterrupted program of survey and inventory carried on almost in the period allowed for capital improvement, attainment of reasonable standards of fire control has aided both the protection and exploitation of the area's resources. Unfortunately, in the absence of both adequate short-term watershed improvement and management funding, the actual multiple-use management of the reserves must, although financially successful, show a restricted future. Adequate governmental investment would be the necessary prerequisite to an effective implementation of the direc-

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[18] [illegible], p. [illegible], Eastern Alberta Forest Conservation Board, [illegible], p. [illegible] (mimeographed).

[19] [illegible], p. [illegible], Eastern Alberta Forest Conservation Board, 1951, p. 1 (mimeographed).

tives given to the Board, including that pertaining to research (see Chapter VIII). Hence the current priority of "protection and maintenance" over both restoration and improvement in Board policy.[20] However, after fourteen years of "watershed management by the Eastern Rockies Forest Conservation Board" its federal member admits ignorance of "the precise location of all areas where damage has occurred and where corrective measures are necessary".[21] This will, however, emerge in discussion of present conditions in the Crowsnest Forest Reserve, bearing in mind the terms of the 1947 Act.

About eighty-four per cent of the funds available for capital expenditure during the period 1947 to 1955 were used to construct roads in the three reserves. This was perhaps the most important feature in the improvement of fire protection, enabling large sections of the area readily accessible both for this purpose and for the other uses to which it has been put. In addition to a section of the #6 millions trunk road from Coleman to Hordegg, there are secondary or access roads which generally connect the ranger stations with settlements to the east and the trunk road, and also modified truck trails. These last are usually closed to the public. Both the existing roads and the new construction by the Alberta Forest Service, oil and lumber companies and the Department of Highways are sources

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[20] Turnbull, G., "Watershed Management by the Eastern Rockies Forest Conservation Board," Forestry Chronicle, Vol. 38, March 1962, p. 92.

[21] Ibid., p. 93. Jeffrey includes a useful description of present watershed conditions on the Eastern Slopes in Prerequisites and Priorities for Watershed Research in the Eastern Rockies, Alberta, Canada, Dept. of Forestry, Forest Research Branch, Calgary, 1961, pp. 8-15.

of sedimentation. Unlike practice in the National Parks, essential stabilization of slopes and ditches through mulching and seeding has not been carried out, and culverts have been badly planned and constructed. Consequently, erosion is common, as for example on the old road up Star Creek and the haul road into the South Canoe Creek basin.

Between 1931 and 1960 (inclusive) over four hundred thousand acres were burned-over in the Forest Reserves, more than ninety-five per cent occurring before 1942.[22] Much of the damage occurred in southern areas, where immature lodgepole pine of fire origin within the past seventy years is by far the most abundant timber class (see Tables 8 and 9 and Photograph 2). Though fire damage had been reduced, it is difficult to find local data regarding its effects on watershed properties, and erosion hazards following fire are by no means uniform. The South Castle and Carbondale River areas respectively exhibit valley erosion after twenty years and no apparent disturbance after only five.[23] Nearly two thousand acres were burned in the 1937 Carbondale River fire which destroyed over one million f. b. m. of sawtimber and much young growth.[24] Burns such as this probably induce temporarily increased discharges, with earlier and higher peak flows. As well as roads, federal capital provided fire

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[22] Data supplied by Western Rockies Forest Conservation Board.

[23] Jeffrey, op. cit., p. 14.

[24] Western Rockies Forest Conservation Board, Annual Report 1957-58, Calgary, 1958, p. 6.

and radio equipment and new lookouts, all in an attempt to reverse the disastrous fire history of the area, though this has been helped by a series of moist years since 1949. Fire protection should result in some improvement in streamflow regimes as the present growth develops.

Soil movement is a feature along seismological trails in the forest, though many have been successfully revegetated by stabilizing vegetation soon after their disturbance. In all, over four thousand miles of lines have been bulldozed through the reserves for purposes of seismic exploration. Some, unfortunately, are characterized by severe gullying, and appropriations have had to be made for limited restoration by the Alberta Forest Service. Since no survey of the damage has yet been made, the problem cannot be correctly assessed. Some are undoubtedly too many diversions caused by lines crossing streams, and long, steep slopes also have little provision for water to return to natural channels. All too frequently, seismic trails and pads have been left to become erosion channels (Photographs 3 and 4).

Oil and gas well sites on dry knolls overlooking streams in the northern part of the Livingstone District are not well vegetated, and there is some movement of soil into streams because of the large areas exposed. Hamon et al. report that the pipeline recently constructed to carry gas from the Swan Creek field to west-coast markets has given rise to excessive watershed damage.[25]

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[25] Hamon, . . et. al., Multiple-use Management Guide, Limon Conservation Unit #2, Eastern Rockies Forest Conservation Board, January, 1962 (unpublished ms.).

pollution of streams by sedimentation and which has been caused by mining operations for bituminous coal on Mount Allan and Grotto Mountains in the Crowsnest area. Methods used in the exploitation of mineral resources require attention, and close supervision is necessary to protect timber areas from the effects of experimental by amateur miners by unscrupulous operators.

Timber operations in the reserves have accounted for about eighty-eight per cent of the annual revenue from all resources during the past five years. The recession of the timber market was the main reason for the reduction in revenue from surface rights to $447,374 in 1960-61 from $534,374 in 1959-60, the former being just over half of the increased albertan appropriation for maintenance and administration.[26] Regulations concerning avoidance of water pollution by logging were not effectively defined until 1961, and may still be considered inadequate. Along with the seismic lines and trails, logging trails and disturbed areas on old berths are in critical need of restoration (October, 1967). Regeneration has been poor on the old cut-over areas which have not produced sufficient natural regeneration to ensure a future crop even after extended periods of time.[27] In exploitation, soil stabilization

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[26] Eastern Rockies Forest Conservation Board, Annual Report, 1960-61, Calgary, 1962, pp. 33-34.

[27] Clyde Moody, et. al., Regeneration on Cut-over and Burned-over Land in Canada, Dept. of Resources and Development, Forest Research Branch, Divis. Rep. No. 92, 1951, 64 pp. and map, and J. D. Bedford and D. A. Duffy, The Problem of Regeneration in Examination in the Crowsnest Forest, Canada, Dept. of Northern Affairs and National Resources, Forestry Branch, Forest Management Division, Calgary, 1960, 97 pp. (unpublished MS.).

was not carried out, and timber was cut along side streamcourses (cf. photograph 3). Some debris c[illegible] diversions, for example that of the Carmanville River, where gullying is still occurring (photograph 14; see also 9, 11, 12, 13). Comstock described choked stream beds in a comparative study of trout stream-life cover in logged-over and undisturbed virgin spruce woods.[28] Most old logging roads appear to have been rendered impassable through erosion, stream sedimentation and bridge destruction.

The recent logging regulations require that there be no cutting of timber within one hundred and fifty feet of a streamcourse, no timber cutting above 650 feet ("protection forest"), no debris to enter watercourses, optimal road location and erosion control on skid trails. Crawler haul and tractor skid roads are a serious source of watershed conditions in the reserve, disturbing the ground surface, provoking soil movement and consequently contributing to erosion, sedimentation and surface runoff. Tractor and jinx, steep, badly-located skid roads, tree-length skidding behind trucks and badly engineered haul roads, whilst justified on the grounds of low costs, are surely not in the best interests of the board's commitments under the terms of the act, and destroy or damage a large part of the residual stand and advance growth (photograph 2). Location such as the west lining long North East Brook give no basis for complacency, and neither does construction

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[28] [illegible] Comstock, J. A. K., "A study of trout stream-life cover in logged over and undisturbed virgin spruce woods (Quebec)", Canadian Journal of Research, D, 17, 1939, [illegible].

in which logging methods required by the operating companies. Current exploitation of some of the few remaining stands of mature spruce, as in the Dutch Creek block, is causing unnecessary disturbance and contributing to overland flow and deterioration. Little is being done in the interests of maintaining satisfactory fish habitats and preserving aesthetic values where recreation is important. Hay and Duffy note that local operators south of the Crowsnest Pass are now logging only two miles from the Continental Divide, and estimate that pulpwood operations in mature spruce and fir stands can only continue for a further seven years (photographs 4, 5 and 6).[29] A considerable time must, then, elapse before the area can be out of the present phase of very low productivity.

There has been a general continuance of clear-cutting and heavy partial cutting followed by logging of the slash, despite research findings that these are incompatible with the ecological requirements of the desirable species, limitation of the fire hazard and preservation of residual stands.[30] Experimental trials were initiated in 1953 involving clear-cutting followed by either broadcast burning or scarification as possible remedial measures. These solutions have encountered a number of difficulties and remain controversial. Provided with adequate seed, both treatments reduced

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[29] Hay and Duffy, op. cit.

[30] See e.g., Orton, C. R., The effect of clear-cutting spruce in Alberta, Dominion Dept. of Northern Affairs and Natural Resources, Forestry Branch, Forest Research Div., Technical Note No. 70, 1959, 20 pp.

in excellent spruce and fir regeneration.[1] However, if the main object of management in the forest is taken to be the maintenance of watershed protection forest, some form of continuous cover would seem essential to the implementation of this policy. Under present policies, timber sale operators make a payment of $1.50 for each thousand f. b. m. cut into a "special regeneration fund", which money is refunded only if "satisfactory" regeneration is secured on the cut-over area.

Wildlife depletion of the range resources in the forest reserve chiefly derives from elk. Heavy winter and spring numbers on south and west slopes show much termination, trampling and soil compaction. Bare soil and scrub growth are common indicators of overgrazing, though the results of domestic grazing activities must not be overlooked in those areas. In general, there is little direct effect by wildlife on watershed conditions, and it adds greatly to the recreational resources of the reserve. Confusion exists about the management of available forage between big game and domestic livestock, and in the absence of explicit policy, uncontrolled grazing by elk poses serious problems for stockmen, a vociferous interest group, with a tight hold on the wide consciousness originally granted to it by the Board. In the Bitterroot River basin above the Big Hole, elk populations have increased considerably in the past

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[1] Cameron, J. A., Regeneration of Douglas fir and associated species after clear-cutting, a reflection survey, Missoula, Mont., Intermt. Forest and Range Expt. Sta., Forest Service, U. S. Dept. of Agriculture, 1961, 24 pp. (unpublished ms.).

two decades, successively gaining greater emphasis for winter range and recently the already fully utilized valley bottoms for use in spring. Cattle numbers have been markedly reduced, as for example in the Gallatin Forest, but some conflicts for protecting wildlife from livestock competition in major recreation areas, many woodland ranges and on high-level meadows. The effects of wildlife other than elk are less pronounced. Damage by deer in the Gallatin Valley is evident, and there is sporadic disturbance from sheep, moose and beaver.[32]

The grazing of domestic livestock in the Crow Unit Forest Reserve continues to be more important than in the other areas under the Board's jurisdiction, owing to such factors as the proximity to farming interests, the area's pronounced summer droughts and the amount of suitable forage available. Grazing patterns are somewhat different from those of big game, and the area is used by livestock almost exclusively in summer. Although summer cattle numbers have been cut[33], and this has contributed toward range improvement, depletion continues, especially on alluvial terraces in eastern mountain valley and foothill areas. These are easily accessible and close to water supplies. Misuse of grazing resources, though less conspicuous than that of the forests, is probably more serious and far-reaching in some respects, deriving in part from the inherent

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[32] Geoffrey, op. cit., pp. 13-14.

[33] The total grazing in the Crow Unit Forest Reserve was reduced from 75,773 A.U.M. in 1945 to 47,436 A.U.M. in 1948.

instability of the underlying soils and also from the climatic conditions found in the larger grassland areas. Effects include crown in the vegetative cover, exposure of bare soil, compaction and erosion, all with deleterious watershed results. Poor grazing practice has been one source of extreme range abuse, which chiefly stems from poor distribution of stock. There has been some terracing and soil-exposure on the steeper slopes through use by livestock, especially where elk concentrate in spring.

Many observers have described the overuse of range and damage to other values. Wessel and Conley, for example, commented upon conditions in the Horse Creek hills during a period soil survey:

> Overgrazing and excessive cattle trailing have resulted in both sheet and gully erosion. The results in the fact that compaction on grounds and cattle trails has left the soil practically impervious to water. Even light rains cause runoff, and rains as heavy as a half inch in three or four hours cause excessive amounts of water to run down roads and trails. During a thirty minute rain, streams in the Horse Creek hills have been observed to change from clear to very muddy, largely as a result of runoff and erosion from roads and trails. Many cattle trails start out the Horse Creek hills are becoming gullied and the situation is accentuated when the cattle trail on the old roads....
> Improper distribution of stock because of poor location of salt and water has caused local overgrazing and almost complete loss of top soil in certain areas. The most obvious example of this type of damage was found on the valley range in the West Horse Creek area where several inches of fine textured top soil have been lost over a fairly large area because of over-concentration of livestock....

Accumulation of burned-over areas is extremely [illegible] by destructive erosion activities [illegible]

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[4] [illegible] Soil Survey of [illegible] Area, Wyoming, 1942. [illegible] pp. 9-12 (mimeographed ms.).

[illegible] of erosion [illegible] It is even doubtful whether [illegible] timbered [illegible] should be grazed by domestic livestock, both from the view [illegible] of the limited forage resources and because of the excessive needs for harvesting. Improvements based upon reduced fire hazards and lower erosion losses may be balanced by [illegible] for trees. Improved litter cover [illegible] may improve infiltration and storage capacity and prevent erosion, while the [illegible] increases in [illegible] runoff will be comparatively small even by the [illegible] erosion.

[illegible] potentially [illegible], use of the [illegible] for recreation [illegible] only when [illegible] the [illegible] trade routes to cities and improved communications. [illegible] facilities such as roads and [illegible] trails are not overly important, commercial services are frequently inadequate, and [illegible] is probably the most popular recreation, [illegible] hunting is also of significance.

[illegible] forest policy and management have so far shown all too little regard for achievement of the forest's original objectives, in which water interests are given legal dominance. The adopted concept of multiple-use is only accepted insofar as [illegible] exploitation causes no unreasonable harm to these values. It is unfortunate that [illegible] values (of the above classes) in economically necessary for the [illegible] of these water and [illegible] facilities have, and that such data [illegible] to the local economy [illegible] are [illegible] in the not overselling[33], or rather [illegible] by the Forest Service. The general guidelines for present and long-term management recommendations on the

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[33] Kennedy, op. cit., p. 60.

CHAPTER VIII

DEFICIENCIES IN RESOURCE INVENTORY AND PRIORITIES FOR WATERSHED RESEARCH

Useful watershed research and action programmes on the Eastern Slopes are only possible given an adequate amount of basic inventory data. This should concern the area under study both by itself and within the framework of the Saskatchewan River Basin as a whole. Upstream management of water resources is to be seen in terms of downstream patterns of demand and their likely trends, with due regard to the other uses of watershed areas. Necessary preliminaries to research on the Eastern Slopes would therefore include a detailed basin analysis, possibly using Durrant's outline as an initial working base.[1] A strengthened Prairie Provinces Water Board might cope with the preparation of this study, and ultimately with a comprehensive plan of development. In its present limited advisory role, however, the Board has been unable to obtain the necessary authority and finance with which to proceed with this work.[2]

The legal and organizational arrangements currently in force deserve study, especially emphasizing the relationship between water

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[1] Durrant, E.F., Preliminary Report on an Integrated Basin Plan for the Saskatchewan River Basin and the Nelson River, Prairie Provinces Water Board, Regina, 1960, 83 pp.

[2] MacNeill, J.W., Law and the Agencies. Paper presented to the Fourteenth Annual British Columbia Natural Resources Conference, Kelowna, Sept., 1962, p. 23. (mimeo. to be published).

rights and organized watershed development and management. The ability of the present administrative structure to meet successfully the complexities of comprehensive development must also be considered. Other needs of this type include the formulation of procedures for projecting future water requirements in the development of sufficiently flexible plans. These would incorporate effective planning methods such as recognition and evaluation of available alternatives. As on the Eastern Slopes themselves, determination of research needs and application of the eventual findings will involve consideration of social, economic and political factors, as well as those of a purely "physical" nature.

Inventory studies carried out during the Capital Period between 1948 and 1955 under the auspices of the Eastern Rockies Forest Conservation Board are outlined and discussed by Laycock.[3] Their incomplete, unintegrated and unoriented nature was one of the reasons why long-term multiple-use plans were not developed by the end of that time. This, coupled with the near absence of basic survey in subsequent years, has left a pressing need for surveys, instrumentation networks and statistical compilation to define and locate present and potential watershed problems, as an essential basis for management and the determination of research priorities, and also for use in the research programme itself. This position must not continue to serve as an excuse for delaying rectification of the more obvious

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[3] Laycock, A.H., A Physiographic Classification of Soils for Land Use Planning on the Eastern Slopes of the Canadian Rockies, unpublished Ph.D. thesis, University of Minnesota, 1957, pp. 30 ff.

abuses to watershed values. Not only on the Eastern Slopes has this been used as "a means of delaying distasteful administrative decisions".[4]

Both the nature and areal scope of these inventory studies depend, as does the research, upon the area thought relevant for watershed management. Ideally, it should encompass the whole Saskatchewan-Nelson Basin, in which the Prairie Farm Rehabilitation Administration might be given wider responsibilities and objectives. At least it should include the basin's mountain, foothill and plains margins sections, in which the Oldman system's headwaters occupy a significant part. Only if watershed research and the preparatory survey work are undertaken within meaningful units can benefits be maximized, always assuming that the results of these studies are allowed of application. Outside the Crowsnest Forest Reserve this might be achieved through such legislation as the "Act to Provide for the Conservation and Efficient Uses of Land, Forest and Water Resources in the Province of Alberta" which was assented to on August 25,1955.[5]

Three major recording networks are required in the area, and these are closely inter-connected with the need for surveys of other phenomena. They would measure climatic, streamflow and snowcover variables, which are all as yet poorly known. Along these lines, the study prepared by McKay for the Technical Advisory Committee (see below) about the weather observation network on the Eastern Slopes

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[4] Costello, D.F., et al., The Integration of Professional Forestry, Range Management and Wildlife Management Responsibilities, Journal of Forestry, Vol. 53, No. 1, Jan.1955, p. 59.

[5] 1955 (Second Session), Chapter 3.

can hardly be said to fulfil its stated objectives, to "outline the requirements" and "suggest improvements to the current network" in anything but a cursory fashion.[6] It does, however, show how urgent is the need for satisfactory information as to climatic patterns. Sedimentation data would be an important product of an improved hydrometric net. These studies would be helpful in establishing the nature of the precipitation and runoff aspects of the water balance. The actual research would incorporate the data surveys in general in establishing the variations in value of all the variables involved. A current lack of suitable classifications must inevitably retard important surveys, such as that of the range resource.

Jeffrey divides the initial reconnaissance survey needs into two groups, the second of which is regarded as less pressing than the first.[7] These comprise, firstly, superficial deposits, groundwater resources, soils, resource damage and downstream water use and demand. Surveys in the second category are of forest inventory in the National Parks, avalanche and torrent areas, areas recently cut-over or burned-over, areas cleared for agriculture, rangeland and water storage sites. Dependent upon these inventories are the crucial surveys of watershed and land management. Optimism about the quality and usefulness of the current forest surveys of the Reserves by the

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[6] MacKay, G.A., Weather Observation Network in the Eastern Rockies, Canada, Dept. of Agriculture, Prairie Farm Rehabilitation Administration, Regina, 1961, 6 pp.

[7] Jeffrey, W.W., Prerequisites and Priorities for Watershed Research in the Eastern Rockies, Alberta, Canada, Dept. of Forestry, Forest Research Branch, Calgary, 1961, pp. 28-29.

Alberta Forest Service seems misplaced, and the overall delay in initiating inventory studies has inevitably meant that much of the work undertaken prior to 1955 has become dated and inapplicable.

Watershed management, in planning and effecting operations to attain desired objectives, presupposes that the limits of potential action, the methods by which this can be accomplished, and the quantitative results are known. Hence there arises the need for research to help answer these questions. Addressing the Fourth Annual Arizona Watershed Symposium, Storey included a useful summary:

> Watershed management research is that broad area of investigation aimed at determining and understanding those elements and processes that affect and control the manner in which a watershed receives and yields water; and further, to determine how these controlling elements may be maintained or modified so as to best meet man's needs as to amount, quality and timing of water yields. Such research is intended to furnish the knowhow needed for management of forest and range watersheds, to provide guides for the rehabilitation of severely deteriorated areas that constitute sources of destructive floods and sediment, to guide activities aimed at protecting soil and water values while carrying on other uses of the land, and to guide programs intended to increase total water yields or improve the timing of yields. A well-rounded research program should be made up of both basic and applied types of studies. The character of applied research will vary dependent upon the objectives of the phase of management to which it is directed.[8]

Prior to discussing basic and applied research needs and priorities on the Eastern Slopes, some comment is pertinent about

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[8] Storey, H.C., Watershed Management Research, Proc. Fourth Annual Arizona Watershed Symposium, Watershed and Related Management Problems, Phoenix, Sept., 1960. p. 8.

the organization and administration of this work. As noted in the Eastern Rockies Forest Conservation Board's Annual Report for 1961-62, it was proposed to set up a single agency control of watershed research, with other agencies acting in cooperation with that (presumably Federal) body.[9] This idea was unfortunately discarded, and consequently the "programme" is being pursued through a multiple-agency group, the Technical Coordinating Committee. A Federal coordinator from the Department of Forestry plans its programmes as well as coordinating the planning, fieldwork and interpretive studies in conjunction with the Eastern Rockies Forest Conservation Board. The Board itself gives assistance to other cooperating agencies. This system, subject to advice from a Steering Committee in Ottawa, has serious limitations. The coordinator does not have the authority or personnel necessary for a satisfactory development of projects. Responsibility for individual projects is difficult to place in this committee administration of necessarily divided loyalties. It is far from comprehensive in its membership, as is to be expected when some twelve agencies should be involved, and when, even if they were all represented, informed opinion on many topics would be lacking. Omission of members from the Provincial Forest Service, Fish and Wildlife Division, Lands Division, and University, and from the Federal National Parks Branch and Geological Survey, must be regarded as a serious stricture, even assuming reasonable calibre among participants. The process by which the

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[9] Eastern Rockies Forest Conservation Board, Annual Report, 1961-62, Calgary, 1963, p. 12.

Marmot Creek project is being undertaken serves as a portent of future efficiency, which could be partially alleviated by devolving responsibility for individual projects upon individual agencies.

A watershed research programme on the Eastern Slopes should have an initial short-term aspect until survey work allows formulation of a long-term, comprehensive study such as that outlined by the Technical Advisory Committee in 1960 (see Appendix I). Meanwhile the problem is to determine which individual objectives are to be pursued in the interim period. Initially, it has been assumed (probably unjustifiably) that watershed management authorities will follow remedial action programmes of rehabilitation using known techniques, though applied research might be necessary where these prove to be inadequate. Likewise, the actual conscious change of water supplies deriving from the Eastern Slopes must await the long-term programme, so that immediate objectives might focus upon basic research and the protection of soil and water resources (i.e. preservation), all taking cognizance of the full range of areal variations found there.

The research coordinator has set up six high priority objectives for research during the period 1962-66 which will be investigated along with other research after that date. Four are concerned with the establishment of underlying hydrologic relationships, and exclude any sort of hydrogeological or meteorological research.

They are defined as studies of

1. the variation between precipitation and runoff relationships for the major hydrologic zones and vegetation types.
2. the variation in evapotranspiration, water losses and consumptive water use in the major vegetation types and hydrologic zones.
3. the major snow accumulation zones and the important relationships between snow, vegetation type and density, topographic features and climatic patterns.
4. the physical characteristics and management requirements of the important soil types from the land management and watershed standpoints.

Two others concern watershed preservation, i.e. to find out

5. the effect of commercial logging in high altitude subalpine spruce-fir forest upon watershed values, notably quality and regime of runoff, infiltration and percolation, soil movement and sedimentation, and to develop techniques for minimization of drainage.
6. optimum vegetation types and plant cover densities, with respect to sedimentation and water regime and to develop criteria for range watershed criteria rating in the minor range types of the study area.[10]

As a part of the long-term elucidation of precipitation-runoff relationships, the subalpine Marmot Creek basin has been set up as an experimental watershed on a rather flimsy basis in an attempt to provide a long-calibrated watershed upon which the integrated effects of the variables studies in the research period can be seen. Similar objectives on the Dry Coulee watershed in the Porcupine Hills have been proposed, but the project has become

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[10] Jeffrey, op. cit., pp. 37-44.

somewhat confused in its "planning" stage, and, further, there are doubts as to whether it is a sufficiently representative basin for study. The role being played by the Provincial Department of Agriculture's Water Resources Branch is a limited one in view of the fact that it is responsible for administering the Water Resources Act, and, more important, for advising the Minister of Agriculture of "works and undertakings which are considered to be in the public interest" under the terms of Part IV of that Act.[11] These provisions exist for direct dealing by the Province with water problems.

The priority given to survey work and basic research studies is common to the suggestions of Wils and Dumford in the central Rockies,[12] Dils in the Lake States,[13] and of both Frank[14] and the Technical Advisory Committee in this area, but it is difficult to understand why conservative management practices cannot be immediately implemented in lieu of knowledge as to how the area's varied resources can be utilized whilst maintaining stable soil, uniform runoff and desirable watershed conditions. It is strange

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[11] Alberta, Dept. of Agriculture, Water Resources Office, Annual Report 1953-54, Edmonton, 1954, p. 71.

[12] Wils H.J., and E.G. Dumford, Problem Analysis - Forest Influences, Rocky Mountain Forest and Range Expt.Stn., Fort Collins, 1941, 62 pp. (mimeo.)

[13] Dils, R.E., Watershed Management Research Needs in the Forests of the Lake States, Michigan State University, Agric.Expt.Stn., Dept. of Forestry, Special Bulletin No. 416, 1957, pp. 25-26.

[14] Frank, B., pers.comm. to W.W. Jeffrey, Canada, Dept. of Forestry, Forest Research Branch, File A-73, Calgary, 1961.

that at the same time as effort is being directed toward protection of soil and water resources, the Annual Report of the Eastern Rockies Forest Conservation Board for 1961-62 states that "Although there is improvement in watershed conditions on range land and timber berths it is probable that, concerning the area as a whole (i.e. the three Forest Reserves), conditions have deteriorated on account of the great amount of disturbance by increased road mileage, oil wells, seismic lines and pipe lines".[15] Rehabilitation needs are increasing as preservation is neglected, but this is taking the discussion out of the realm of watershed research per se and into a consideration of present and long-term management requirements (see Chapter IX). In this, however, it might be argued that once the survey work has been organized, channelling of limited personnel and funds away from the four basic research studies and into rehabilitation research and its application would be desirable, given sufficiently strong directives against continuing damage. Soil movement is an inevitable constituent of most activities on forest and range land, so that the question is, how much damage can be tolerated and how much is economically avoidable. Intangibles limit the suitability of simple benefit/cost analysis as an answer to this problem, but some guidelines are urgently needed to find out how much added costs

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[15] Eastern Rockies Forest Conservation Board, op. cit., p. 9.

in watershed management are justified. As in the research programme priorities described by Dunford for the Pacific Northwest of the United States, selected lines of investigation into the causes and rectification of disturbance should merit immediate attention.[16] These should include not only the watershed rehabilitation and preservation objectives noted above, but also research into techniques for minimizing soil movement along roads and seismic lines. Costs for the last of these could reasonably be levied against the prospecting companies, though provisions for the other research priorities must derive from the two Governments, unless Reserve users and downstream beneficiaries are to be properly assessed.

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[16] Dunford, E.G., A Watershed Research Program for the Pacific Northwest, Proc. Society of American Foresters, 1955, p.194.

CHAPTER IX

PRESENT AND LONG-TERM MANAGEMENT REQUIREMENTS IN THE CLOWAN RIVER BASIN

It has been shown that inventory studies are essential in locating and predicting management problems on the Eastern Slopes, as well as providing a firm basis for watershed research. At present, action requirements in the form of watershed rehabilitation in the Crowsnest Forest Reserve would seem to be a far wiser investment of limited funds than would the initiation of basic research. The preservation of watersheds, which has been given priority over restoration,[1] could be substantially aided without research were a conservative management policy substituted for the present exploitive approach, and this would curtail spiraling rehabilitation problems. It would be unfortunate if failure to protect watersheds in the face of rising water needs resulted in de-emphasis of multiple-use, as has happened in some parts of the United States.[2] Increasing use of water on the Prairies should ensure watersheds a dominant position well into the future. As far as immediate needs are concerned, these fall into two inter-related groups: use-conflicts deleterious to watershed conditions, and resolution of conflicts amongst the other uses now being pursued

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[1] Tunstall, G., Watershed Management by the Eastern Rockies Forest Conservation Board, Forestry Chronicle, Vol. XX, March 1962, p.93.

[2] Bailey, ..., The Challenge to Watershed Management, Proc. Forestry Centennial Conference, Feb. 1959, Corvallis, 1959, p.61.

in the Forest.

Some problems of use requiring rectification were noted above in Chapter VII, and research in other parts of the world, notably the United States, into remedies for erosion and sedimentation, could certainly be applied here with success. These concern unwarranted damage on overgrazed lands, logging and forestry roads, seismic lines and along streamcourses, all of which can be avoided by stringent controls in the future. For example, in the upper Oldman and Crowsnest River basins, which supply water to the Lethbridge Northern Irrigation District and the proposed Oag reservoir site, the timing and quality of streamflow are especially important. There, logging roads and skid trails continue to cause loss of soil and stream sedimentation, and logging damage and debris build-up lead to stream channel changes. Stabilization should be carried out and the debris removed, the roads themselves to be relocated wherever necessary. Extensive clearcutting of forests in this same intermountain area is endangering stream channels by increasing the total volume and peak loads of Dutch and Racehorse Creeks, and may, unless well executed, cause intensified flood conditions and undesirable low flow periods downstream. There is a particular need for the protection of young growth from fire, especially where infiltration capacities are low on the finer tills and clayey residual soils.

Some stabilization is needed on the new seismic lines, and

roads which present serious erosion problems, as at Vicary Creek, and the gas pipeline through the Livingstone Valley, must be prevented from causing damage. Further correction of sediment and slash in streams from Vicary and Tent Mountain mines is desirable. Grazing has been excessive in the Racehorse, Oldman and Livingstone Valleys, but signs of misuse are less conspicuous than in the timber-cutting zones, though in the former recovery presents far more serious problems. Impairment of watershed conditions must be avoided in the future, and some gully control and reseeding should be initiated. Even so, grazing lands in the Reserve are generally in much better condition than they were in the late 1940's. Presence of far worse abused watersheds in Colorado and Utah must not, however, become a soporific for complacency.

The clear-cutting of high elevation timber berths on the Dutch, Beaver, Savanna and other creek watersheds to an arbitrary three per cent maximum cut of mature and over-mature timber is justified as avoiding waste, though too much of it is being inexpertly cleared. A measure of erosion protection on steep slopes, for example, would be helpful, though fortunately the area is one of high winter snowfall and relatively low intensity summer rainfall. It could be argued that commercial grazing activities in the Reserve should be severely curtailed in the partial interests of improving watershed values, especially in the front range-foothills areas.

The fire hazard would not necessarily increase, and economic justification for use on the grounds of stabilizing ranching units would appear to have been over-estimated. Neither wildlife nor recreation conflict seriously with priorities within the forest, and those uses will merit considerable expansion in the future.

Aside from the impact of these respective uses on watershed values, lack of definitive policies has led to a measure of conflict amongst the other uses themselves. As there is no operative cooperation between the Eastern Rockies Forest Conservation Board and the Provincial Fish and Wildlife Division, indeterminate allocation of forage between elk and domestic livestock continues. Pending inventory and research studies, an interim decision should have been made some time ago. Inferior remunerations from wildlife may be a reason why the Board considers that "The solution to the protection of range used by domestic livestock and elk does not lie in the reduction of cattle numbers".[3] If carefully managed, there is a place for both in the forest under the adopted "multiple-use" policy. Uses might reasonably be given priority on winter and spring forage grounds, with some provision for supplementary feed in severe winters. Summer grazing by cattle on cut-over areas of bottomland alluvium

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[3] Eastern Rockies Forest Conservation Board, Annual Report, 1957-58, Calgary, 1958, p. 27.

is harming forest regeneration, whilst the absence of forest fires is necessitating stocking reductions, as in the Gap Allotment. In the maintenance of suitable, clean fish habitats, as in all the other conflicts, considerate management of the individual components in the multiple-use complex is desirable. While there is quite a range of land-uses present, only a few are involved in individual areas, thus aiding in the resolution of the conflicts. The concept of exclusive uses in some parts of the Reserve, though difficult to manage, must be seen as an important guiding objective.

Recreation in general is difficult to evaluate in terms of its tangible benefits to society, as also has proved the high value of controlled water supplies. In contrast, the financial returns accruing from timber and grazing exploitation relative to administrative costs are easily summated. Little outside token recognition has been done in the interests of recreation in the Reserve, which is potentially of considerable worth and might serve certain needs as well as, or even better than, the National Parks. Fish and wildlife resources, together with tourist possibilities, command much less economic and political power than do the co-equal, competing uses, even though harm to these uses need be only minimal. The attractiveness of the relatively unused western part of the upper Oldman basin stands threatened by timber and other interests in the absence of responsible recreational land-use policies.

Defined as "the matching of water supply to the existing and potential demand for water and water services",[4] water development in the Prairie Provinces, and each component basin, can only achieve efficiency through carefully planned management. The present study is not, however, predominantly concerned with arguing the need for comprehensive development of the Saskatchewan-Nelson River Basin,[5] and stress is laid upon the requirements for protection and enhancement of water resources in the mountains, foothills and plains' margins of south-western Alberta. Projected areal demands for water of a particular quantity and quality would be easier to satisfy under planned development than through a process of market allocation with limited provincial and federal directives. The priority system of water allocation, the lack of acuity in using the provisions for action now in existence, and the ineffectuality of the Prairie Provinces Water Board and the Alberta Water Resources Branch, are hardly designed to foster efficient, beneficial use. Fully comprehensive water resource development has not been adopted as policy chiefly because the need for it has not been felt to be sufficiently acute, and also

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[4] Ackermann, W.A., The Impact of New Techniques on Integrated Multiple-Purpose Water Development, United States Senate, Select Committee on National Water Resources, Water Resources Activities in the United States, Committee Print No. 21, 1960, p. 1.

[5] Vide Fox, I.K., and L.A. Craine, Organizational Arrangements for Water Development, Natural Resources Journal, Vol. 2, No. 1, April, 1962, pp. 6 ff.

because of the nature of the British North America Act in effecting a restrictive division of jurisdiction. There is need for a flexible administrative framework incorporating a variety of structures, taking into account the limitations imposed by the Constitution, and being adaptable to new ideas of resource conservation. Stephens and Kristjanson, in discussing the possibilities of planned multi-purpose river basin development for the Saskatchewan-Nelson, emphasize the primary need for the major parties at interest to "set about to discover the extent to which they have interests in common which could be advanced by comprehensive planning and development within this immense basin. If they fail to find a common purpose or common purposes, presumably there is no reason for organizing a group representing these particular parties...." [6]

Currently, several agencies administer the relevant watersheds of the Eastern Slopes, only a portion of this decisive area being managed with statutory concern toward watershed values. Unfortunately, Provincial disinterest in the conservation of water supplies has not helped even the Forest Reserve, on which watershed

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[6] Stephens, D.M., and K. Kristjanson, Planning River Basin Development. Paper presented to the Fourteenth British Columbia Natural Resources Conference, Kelowna, Sept., 1962, p.12. (mimeo to be published). Vide Canada, Dept. of Northern Affairs and National Resources, Resources for Tomorrow Conference; Conference Background Papers, Vol. 1, Ottawa, 1961, pp. 209-277, and Conference Proceedings, Ottawa, 1962, pp. 129-143 and 321-340.

priorities are theoretically dominant, whilst action further east has been lamentably restricted in scope. Establishment of the Reserves was, according to the Federal representative on the Eastern Rockies Forest Conservation Board, unique in Canada, in that it was "established for water-yields, rather than flood control", and further, that "it is not a problem area where a rehabilitation job has to be undertaken in order to repair damage brought about through mismanagement in the past".[7] This latter statement is not a little inaccurate, at least as far as the Crowsnest Forest is concerned. There, rehabilitation has not yet been seriously attempted, and capital expenditure has been confined to the "preservation" of what resources remain, in the interests of their optimum, cheapest exploitation, to the detriment of the watersheds. Further, omission of the area from the "Resources for Tomorrow" Conference held in Montreal in 1961, is surely perplexing in view of its status and peculiar nature.

Remembering the small area involved on the Eastern Slopes in Alberta relative to its importance in the Saskatchewan-Nelson River Basin and Canada in general, and the need for efficient application of opposite policies, a single planning control appears desirable, with wide statutory powers to carry out its recommendations on both public and private lands. This would constitute a preparatory step toward eventual integration with the whole basin as a unit, and would also be given intimate, relatively uncomplicated relations with the

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[7] Tunstall, op. cit., p. 67.

research agency discussed in Chapter VIII. Matters of policy would be open to free discussion and control by government, this only insofar as there be no interference with the detailed administration of the watershed. It might be reasoned that the two, management and research, could be profitably fused since they are so closely related, thus initiating one body which would be responsible to the people, and charged with overall water resource development relative to the social and economic needs in the basin.

Responsible planning control, in managing the Eastern Slopes as a unit, would require a willingness on the part of the Province of Alberta to forego some of its "rights", and also a realization that short term monetary loss in a particular sector is not always to be avoided. On the plains' margins and foothills, conservation could be encouraged and intensified through a measure of subsidization and inspection. Waterton National Park is, like the other Canadian National Parks, primarily devoted to recreational land-uses, but insofar as these conflict with watershed conditions, as for example in lack of control of grazing by wildlife, the Federal Government should allow intervention in the national interest at the request of the planning control agency. As to the question of restoration and development of the Parks' watersheds for optimum streamflow, this could well fit in with recreation and need not interfere with the ideals underlying the initiation of the Parks.

In the Reserve itself enough basic relationships have been worked out to justify rudimentary land-use planning. Detailed management plans should be formulated according to areal differences and priorities of use, though admittedly these predicate a satisfactory inventory base which is not at present of sufficient accuracy. Only when this last has been completed and a research programme carried out will it be possible to determine how much the vegetative cover can be changed for watershed improvement, or employed for other uses without damage to watersheds. Different types of protection, restoration and improvement are needed in different parts of the Reserve because of variations in physical conditions, whilst the degree of alteration, for example of the vegetative cover, must be related both to the need for change and to the potential responses in each area. "It is desirable that we define as closely as possible those areas that will respond to intensive management for yield increases, quality improvement, flood control, regime improvement, forage increases to meet seasonal needs, timber production and many other objectives of multiple-use of the Reserve."[8]

The potential for augmenting annual water yields by vegetative manipulation in southwestern Alberta is not very great, and quite local. Making a very generous estimate, Laycock concludes that

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[8] Laycock, A.H., A Physiographic Classification of Soils for Land Use Planning on the Eastern Slopes of the Canadian Rockies, unpublished Ph.D. thesis, University of Minnesota, 1957, p. 345.

management might conceivably increase dry year streamflow up to fifteen thousand acre-feet (two per cent) in the Crowsnest Forest over a short period of time.[9] Present "high" yields deriving from past burns and logging operations will, however, decrease as regrowth advances. It is evident that management priorities should stress useful regimes, water quality, and flood control, which will also necessitate a measure of expensive artificial storage. These objectives, especially regime improvement, with which the other two are closely connected, apply to much of the area, but it is important that priorities be specified amongst the various watershed management purposes for each part of the Reserve: flood control on some foothills watersheds such as Willow Creek, quality improvement when over-use generates erosion and possibly water yields in back range drift basins.

An increase in the vegetative cover through regrowth and conservative management would help delay and reduce flood peaks through retarded snowmelt, improved infiltration, and increased detention and retention storage. Through transpiration losses this would reduce total yields. The treatment should be most effective in the front range and foothill areas of the Crowsnest Forest, with their shallow soils, low infiltration rates and frequent high intensity

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[9] Ibid. p. 272.

storms of long duration. These and like policies could be steadily modified as watershed research progresses. Major contributions from research will be over a long period of time, so an interim policy of restoration work, coupled with improved management practices aimed at maintenance, would be appropriate. Again, however, development of suitable artificial storage has a complementary role to that of watershed management, and possesses important advantages in enabling provision of known volumes where and when required, from large water storage capacities. Meanwhile, the appended hydrographs, with their flashy peaks and low base flows, are far from ideal on streams issuing from a "Forest Conservation" area.[10]

In conclusion, management policy trends in the Oldman River Basin, under whatever control, must be confronted by the seven general requirements indicated in a Committee Print of the United States Senate Select Committee on National Water Resources:

1. Acceleration of soil and water conservation on farms and ranches. Intensify programs of assistance to farmers and ranchers to help them use and treat their land to reduce erosion and the rate of runoff, and to increase the efficiency of use and transmission of irrigation water.

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[10] cf. Kennedy, H., Water Conservation on the East Slopes of the Rocky Mountains. Address to the Royal Society of Canada, Ottawa, 1951, p. 8. (typescript) states that as the most pressing need is for water in drought periods, some chances will inevitably have to be taken with local floods, at infrequent intervals, the effects of which can be mitigated by works created outside the Reserve.

2. Better management of forest lands. Facilitate programs for the prevention of overcutting, destructive logging methods, over-grazing of forests, and carelessness with fire. These are still too prevalent as common practices on large acreages of forest lands - and thus substantially reduce the effectiveness of forests as protectors of water supplies. Accelerate reforestation and other constructive forest conservation activities.

3. Improvement of vegetative cover on rangelands, including better management of grazing. Use of ranges by livestock and game should conform to standards which will maintain satisfactory watershed cover. Revegetation should be undertaken promptly where cover is badly deteriorated.

4. Increased assistance to local organizations for watershed protection and flood prevention....

5. Control of phreatophytes. Nonbeneficial high water-using species.... should be held in check. At the same time water used by vegetation that prevents erosion or harmful sediment movement should be recognized as an essential use.

6. Acceleration of research. Acceleration of the agricultural and forestry research programs.... Specifically, there is an urgent need to increase our knowledge of the hydrology of forest and agricultural watersheds as affected by different intensities, types, and techniques of use, in order to develop comprehensive water programs.

7. Educational, technical and financial assistance. In order to fully implement the items listed above, there is need to provide adequate education for the public. There is also need to provide technical and financial assistance to landowners in certain aspects of conservation.[11]

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[11] United States Senate, Select Committee on National Water Resources, Water Resources Activities in the United States, Committee Print No. 13, Estimated Water Requirements for Agricultural Purposes and their Effects on Water Supplies, Washington, 1960, pp. 15-16.

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APPENDIX I.

THE TECHNICAL ADVISORY COMMITTEE'S
WATERSHED RESEARCH PROGRAMME

I. Basic studies

a. Climatic

1. Precipitation, amount, intensity and season.
2. Snow pack and melt characteristics.
3. Frost penetration.
4. Humidity, wind, temperature and radiation.
5. Interception of precipitation by types of vegetation.
6. Micro-climatological studies to compare small differences with varying types of cover.

b. Soils

1. Soil survey to determine major types.
2. Determine the hydrologic and erosion characteristics of the various soil types.

c. Hydrologic

1. Surface water yield of various drainages.
2. Water losses due to evaporation and transpiration.
3. Sediment loads in streams and their sources.

d. Geologic and Groundwater

1. Geologic characteristics of the conservation Area as they affect the general characteristics of the watershed.
2. Ground water investigations.

II. Studies to evaluate protection practices

a. Study to determine to what extent and by what methods can mountain ranges be grazed without damage to watersheds.

1. Project to determine how much and what kind of vegetative cover is required to cope with intensity of rain and snowmelt encountered upon typical soil types and slopes.

2. Determine stocking rates and management practices which will ensure the required plant cover.

b. Study to determine where and in what pattern timber can be cut so as to maintain watershed values.

1. Snow accumulation at various altitudes and under varying degrees of crown cover opening.

2. Snowmelt at various altitudes, on different slopes and under degrees of cutting and size of openings.

3. Determine overall watershed effect of logging a watershed by best known methods.

c. Studies to determine how logging roads can be located and constructed and maintained to prevent or reduce soil movement.

1. Survey of existing roads to determine damage to watersheds.

2. At what intervals must water be removed from road surface

3. What vegetation and mechanical means are effective in preventing sediment flow to streams?

4. What means can be applied on abandoned roads and landings to reduce overland flow and erosion?

5. Determine maximum stable slopes on cuts and fills for various soil types.

d. Determine methods of seedbed preparation (scarification to induce forest regeneration) which do not cause accelerated overland flow and erosion.

1. Determine effects of various methods of scarification upon water and soil relationships (overland flow, erosion and soil moisture accumulation and retention).

2. Pilot test of best methods.

III. Studies of methods of restoring damaged watersheds

a. Determine detrimental effects of fire and methods of restoring burned-over lands.

1. Determine effect of fire upon soil, infiltration and percolation rates, overland flow and soil movement.

2. Discover best methods to restore normal watershed values.

b. Determine effects of logging upon watershed.

1. Study the effects upon infiltration and percolation rates, water-holding capacity and water yield caused by common logging practices.

2. Study vegetative cover resulting after logging for their suitability as watershed cover.

3. Study methods of restoring suitable vegetative cover to improperly logged land.

c. etermine methods of restorin good watershed conditions upon damaged range land.

1. hat species are suitable as watershed cover

2. ow can these species be established?

3. ost economical methods of healin up gullies.

IV. tudies to etermine ethods of Watershed Improvements

a. etermine how and to what extent can such structures as drift fences and planted windrows be used to accumulate snow and retard melt.

1. tudy methods most effective in drifting snow,

2. tudy the effect of drifting upon delay of snowmelt and loss by evaporation,

3. est likely methods upon a small watershed.

b. hat methods can be used to retard water movement so as to increase streamflow in low months

1. etermine effect of spreading spring runoff on pervious soils over deep valley fills,

2. etermine effect of beaver dams on the low flow characteristics of streams

c. ow and to what extent can water yield be altered by manipulation or vegetation

1. etermine effect of timber removal upon total yield, timing and quality of water,

2. etermine value of alternate vegetative covers for watershed,

3. etermine the effect of removal of riparian vegetation upon streamflow,

4. etermine effect of replacing deep-rooted species (poplar and willow) by shallow-rooted ones, (grass) upon deep soils.

APPENDIX II

PHOTOGRAPH:

(Canada, Dept. of Forestry
Forest Research Branch,
Calgary, 1961)

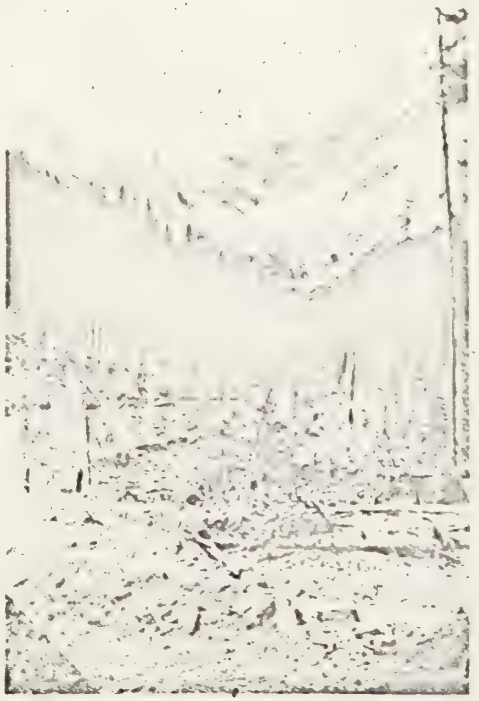
1. Steep, sparsely vegetated slopes.
Upper Oldman River Valley.

2. Burned-over slopes. Castle River Basin.

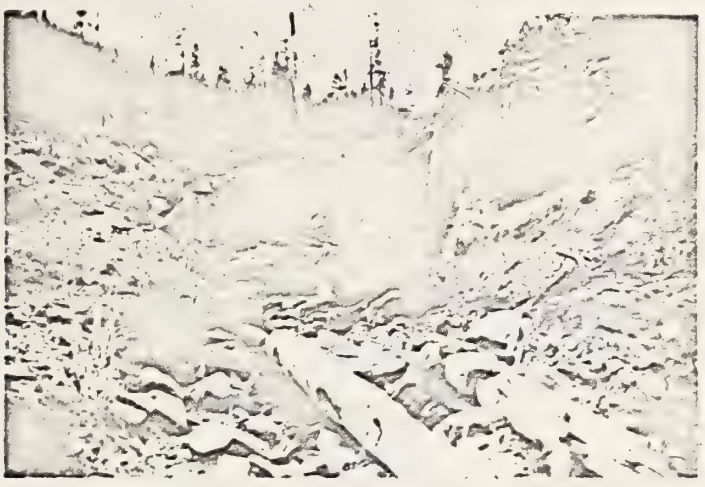
3. Cutting areas in the South Boot Rock Area.

4. Logging area with the range forming the Continental Divide in the background.

5. Typical back-range logging area. Coat Creek Basin.



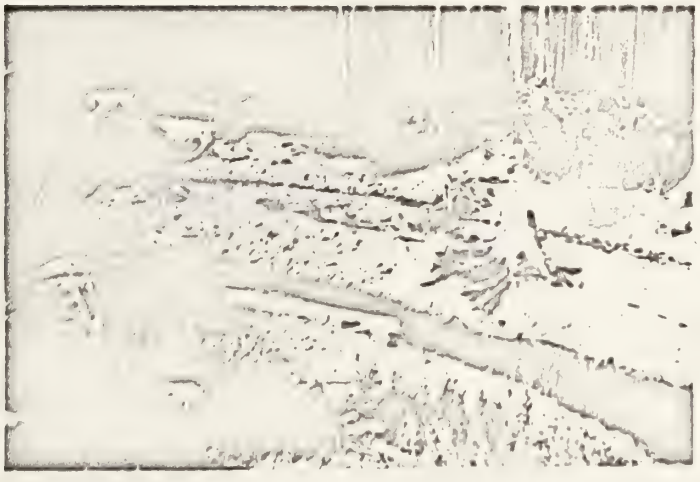
6. Timber cutting area. Coat Creek Basin. Operations are currently extending up to the edge of the corrie.



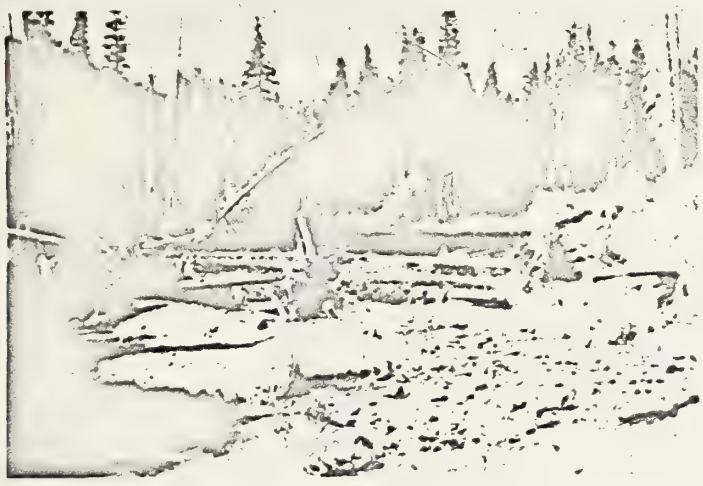
7. Gullies in an old logging area.
Gardiner Creek Basin.

8. Soil disturbance, slumping and
loggin.. South Lost Creek Basin.

9. Lynx Creek. Logging debris in the stream-bed. The ranging pole marks the previous year's bank position.



10. Low August streamflow in Lynx Creek.



11. Logging debris, Lynx Creek.

12. Log jamming on the South Castle River,
probably deriving from fire.

1. ebris choking the channel of ardiner Creek, causing deposition of sediment behind the barrier.

1. ully caused by a diversion initiated by lo ging debris. artondale river basin

15. Junction of North and South Fost Creeks during a summer storm. While the river is paralleled by a badly constructed haul road, the latter has a stream allowance. Sand bar in foreground.

16. Erosion on an old logging road. Lynx Creek basin.

19. Erosion from a culvert along a poorly constructed forestry road leading to Lynx Creek ranger station.

20. Gullying along an old road, south fork Crook Arm.

21. Lupine on a winter mild road. South
East Creek Basin.

. Lupine on a winter mild road. South
East Creek Basin.

23. Gullying by diverted runoff on a steep, cleared colluvic line. Tsuquo Creek basin.

24. A steep colluvic line altering a stream course in an old disturbed logging area. Gardiner Creek basin.

APPENDIX III

Notes

Figs. 2 and 3. The basin of the Castle River above the gauging station near Beaver Mines covers nearly 320 square miles and includes most of the backrange area in the Crowsnest Forest Reserve south of the Crowsnest Pass, together with a part of the eastern slope of the front range to the east. In 1949, a particularly dry year in southwestern Alberta, the peaks were small though sustained and most of the flow derived from relatively dependable back-range snowmelt. Although the maximum effects of incursions of warm, moist mT air in June, 1953 after a wet cool spring were not experienced here, high snowmelt discharges were heavily augmented by runoff from that source. Flows were characteristically low in winter, late summer and autumn.

Figs. 4, 5 and 6. With a gross drainage area of over 475 square miles, the Belly River above Standoff drains a part of the mountain ranges of Glacier National Park (Montana) and a large area of low foothills and plains. Much of the comment made above applies respectively to the 1949 and 1953 graphs. Comparison of the graphs of mean daily discharges for individual months in the water-years 1948-49 and 1952-53 in Fig. 14 of the Belly at the International Boundary and at Standoff illustrates the extent to which the low foothills and plains contributed to the 1953 flood at Standoff. An early peak from plains snowmelt, flashy flows from spring and summer rainstorms, important back-range snowmelt and a particularly well sustained late summer and autumn flow characterize the 1951 curve.

Figs. 7 and 8. The Oldman River Basin above Lethbridge, the river's lowest gauging point, covers over 6,700 square miles (under 5,000 square miles on a "dry" basis), and includes contributions from the Waterton, Belly and St. Mary Rivers. All the different upstream components are summated here: mountains, foothills and plains (see Table 7). In 1941, a very low flow year, the influence of drainage area in smoothing out peaked sub-basin curves is evident. Record discharges were noted in 1948 at such gauges as the St. Mary at Lethbridge, the Belly at the International Boundary, the Castle at Beaver Mines and Oldman at Monarch. These, deriving from storms in late May and June which augmented above average winter snowfalls in higher areas, produced the high discharges at Lethbridge. The mean water content of the snow-courses used in the St. Mary Snow Survey were the lowest in thirty years in 1941, while the content was particularly high in 1948, when contributions to streamflow were pronounced in June and July. Earlier snowmelt came from eastern mountain areas, the eastern slope of the front range and lower parts of the basin.

Figs. 9 and 10. Rising in the Crowsnest Forest Reserve on the eastern slope of the front range, but chiefly draining foothills and plains areas, Pincher Creek's watershed above Pincher Creek townsite is approximately fifty square miles in area. The striking contrast between 1914 and 1915 illustrates well the variability of such streams both annually and seasonally and their immediate response to intense rains of long duration in rapid succession.

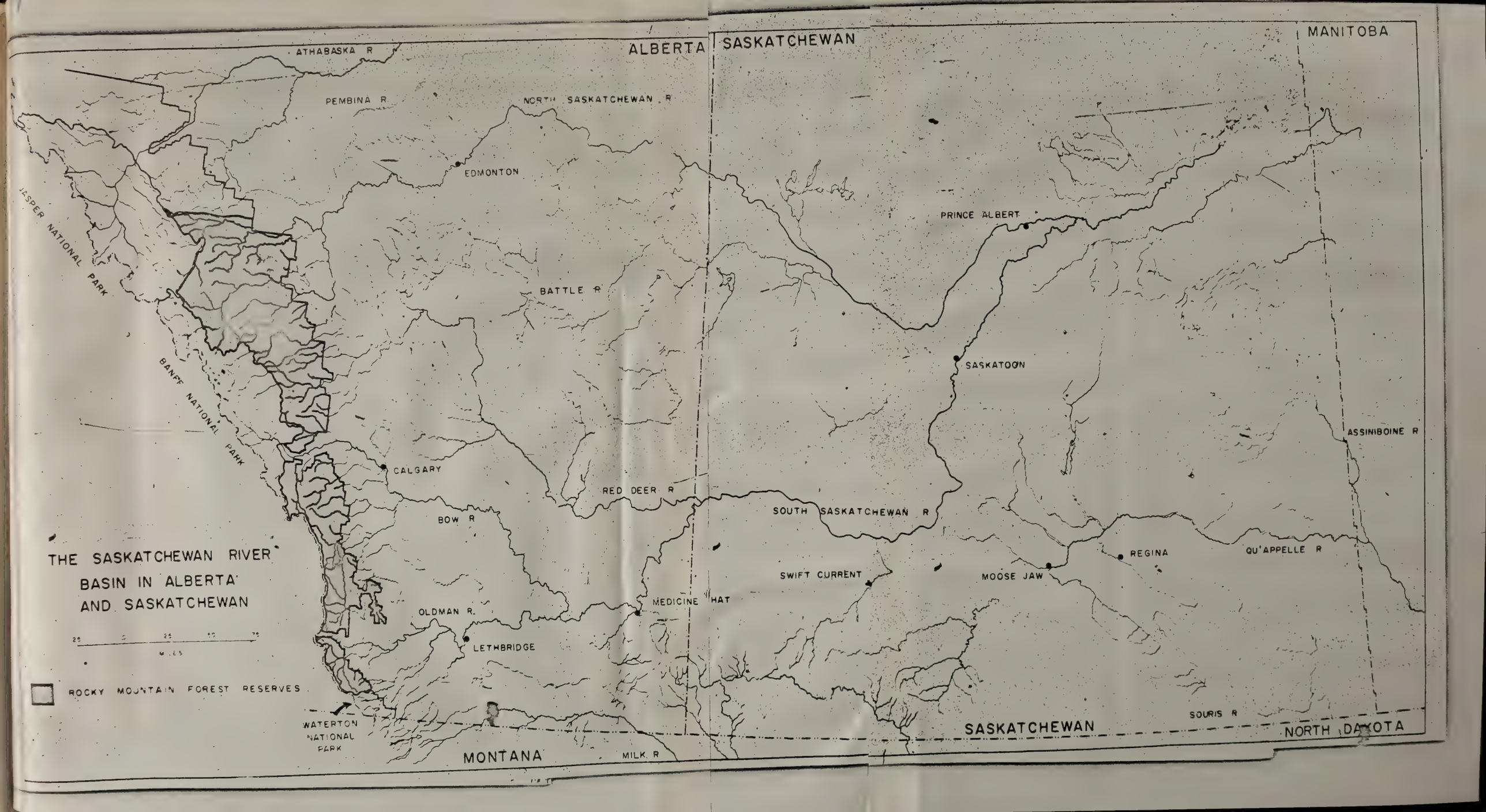
Figs. 11, 12 and 13. Much the same characteristics are illustrated by the curves for Trout Creek above Lockwood's Ranch in 1914, 1915 and 1916. The basin covers over 160 square miles, i.e. almost all of the northern portion of the Porcupine Hills section of the Crowsnest Forest Reserve, as well as a part of the plains to the east. It is probable that the erratic, flashy regimes were partly stimulated through deterioration of watershed values owing to misuse (see Chapter III). Local reports suggest that there was little water in storage when the May, 1915 rains began.

Fig. 14.

Gauge No.	Stream	Gauge	Drainage Area[a] Dry	Gross
1	Waterton R.	Standoff	555	695
2	Castle R.	Beaver Mines	b	319
3	Waterton R.	Waterton Park	236	238
4	Belly R.	Internat. Bdy.	74	75
5	Swiftcurrent Ck.	Many Glacier	32	32
6	St. Mary R.	Internat. Bdy.	497	516
7	Lee Ck.	Cardston	112	112
8	Ralph Ck.	Kimball	45	66
9	Belly R.	Standoff	356	477
10	Willow Ck.	Claresholm	430	462

(a) See Chapter IV, footnote 1. Areas are in square miles.
(b) Not known.

The discharge data used in Figs. 2-14 was supplied by the Water Resources Branch of the Federal Dept. of Northern Affairs and National Resources (Calgary) and the hydrographs (Figs. 2-13) were drawn by the Hydrology Division of the Alberta Water Resources Branch (Edmonton).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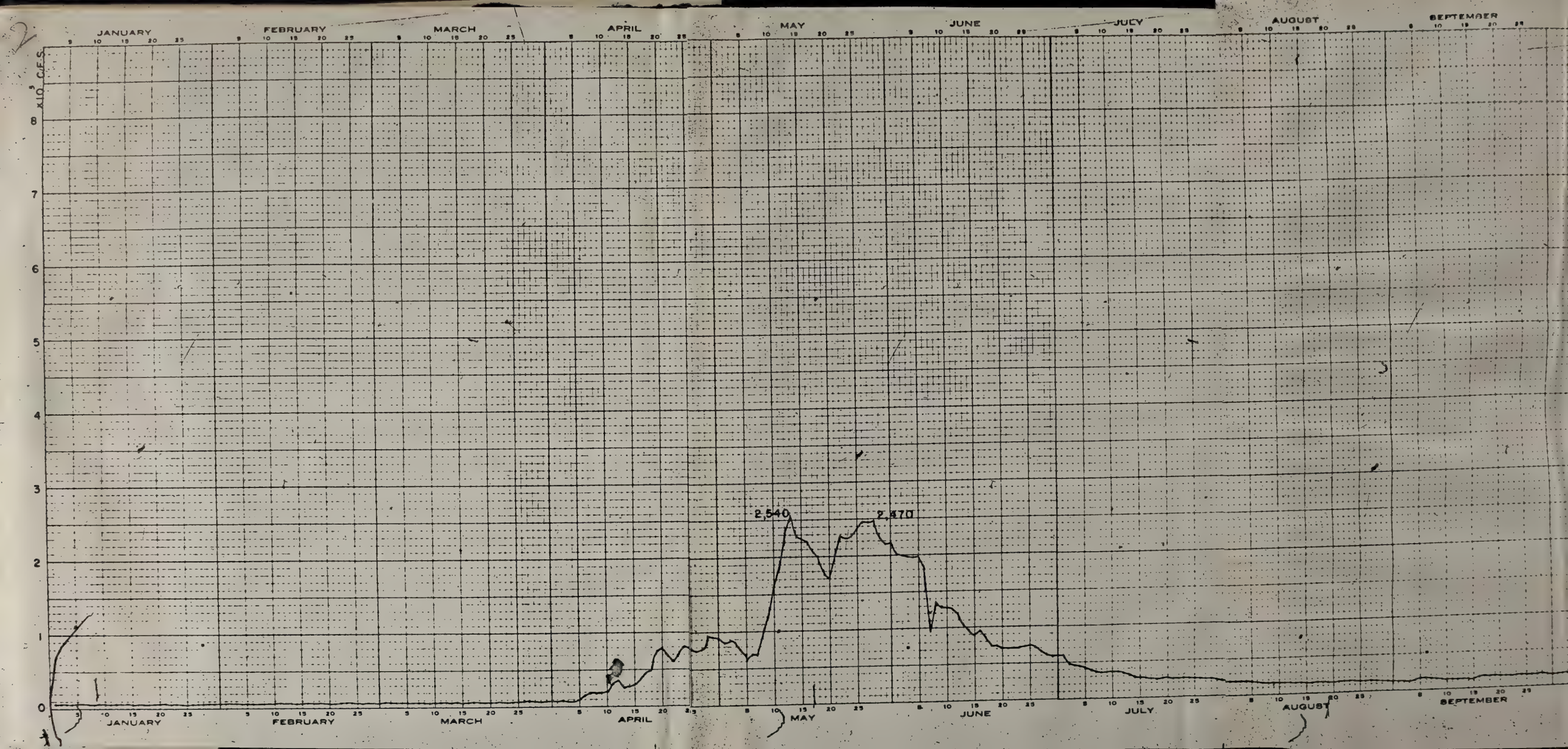
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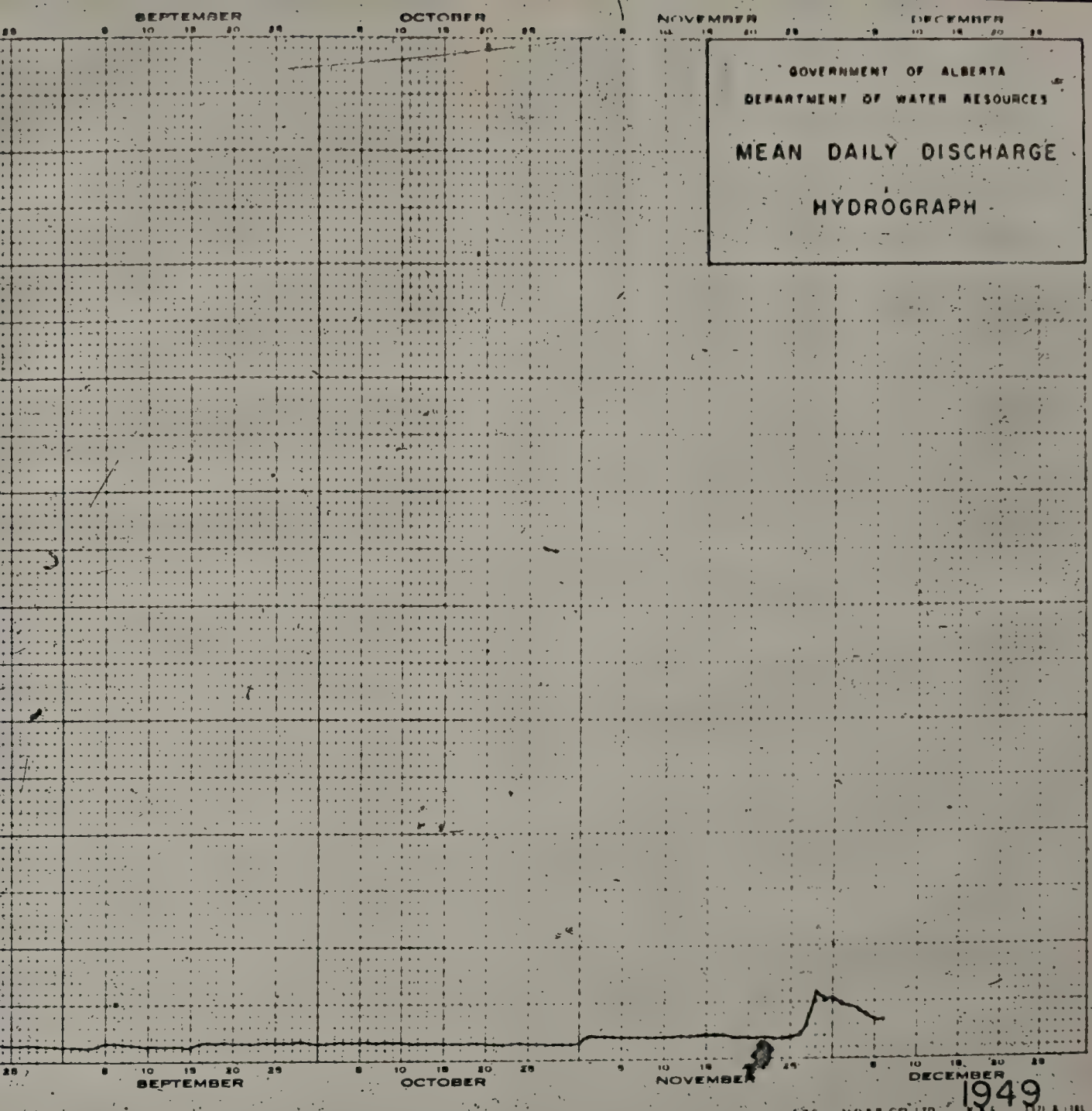
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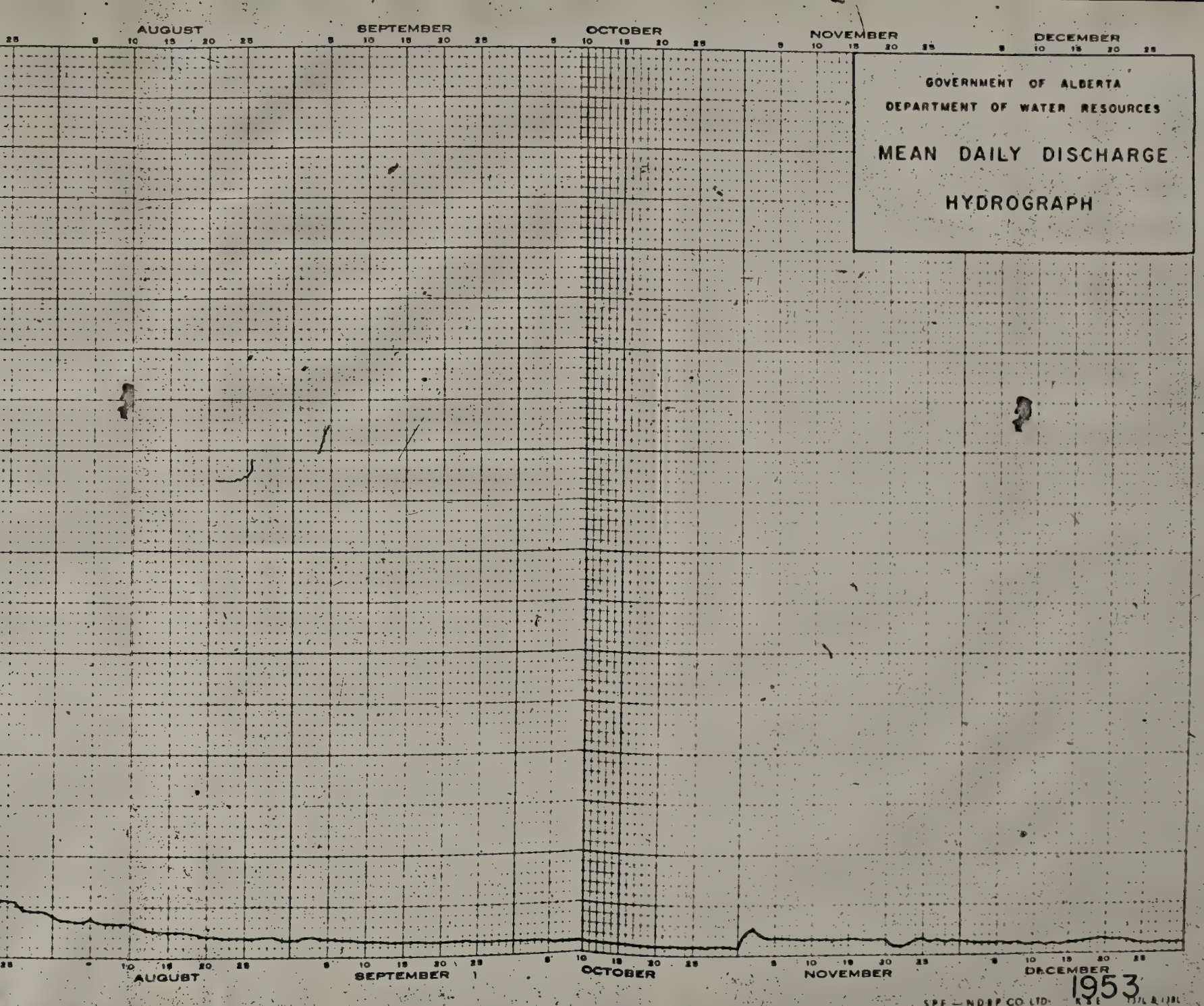
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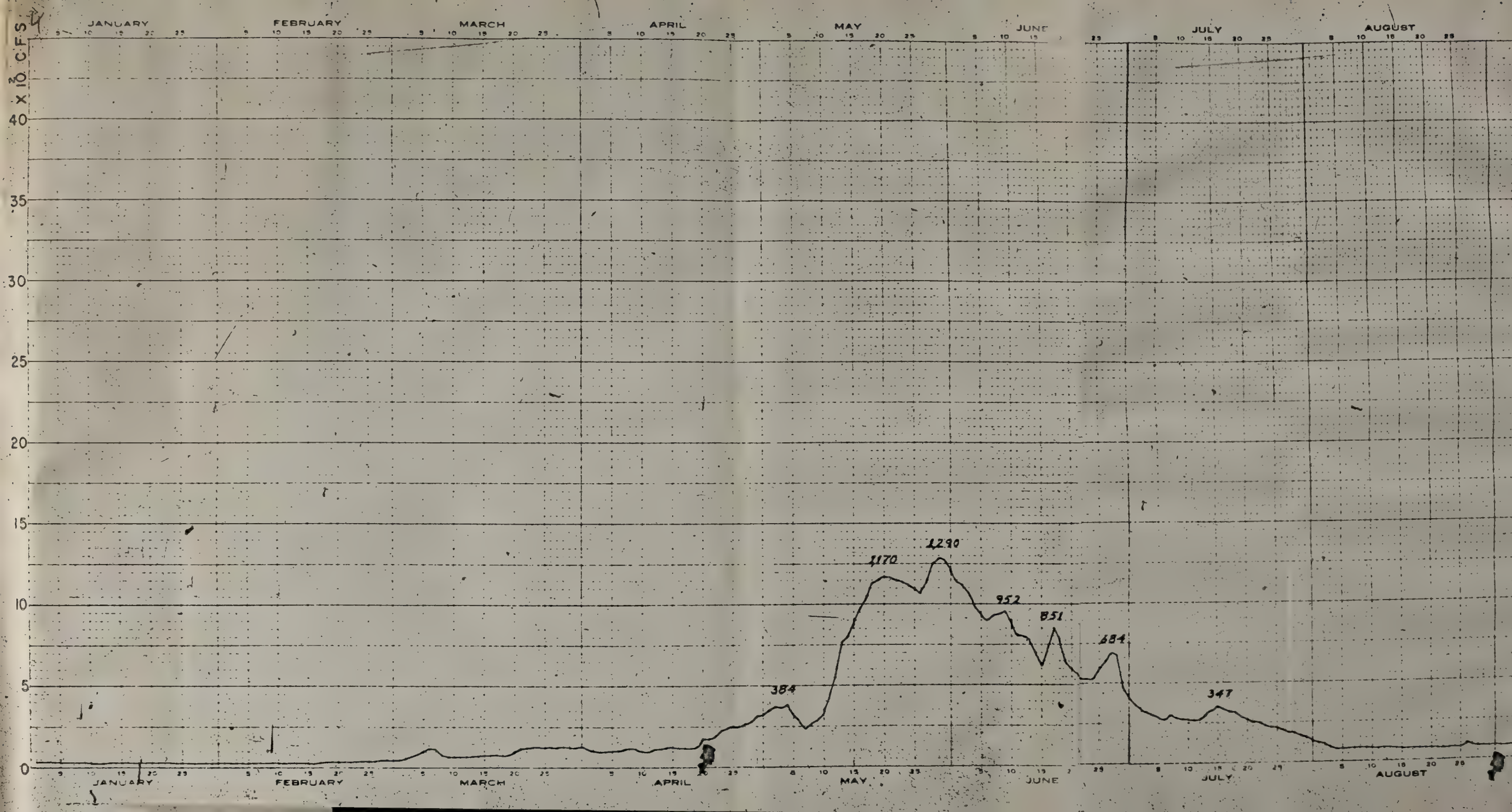
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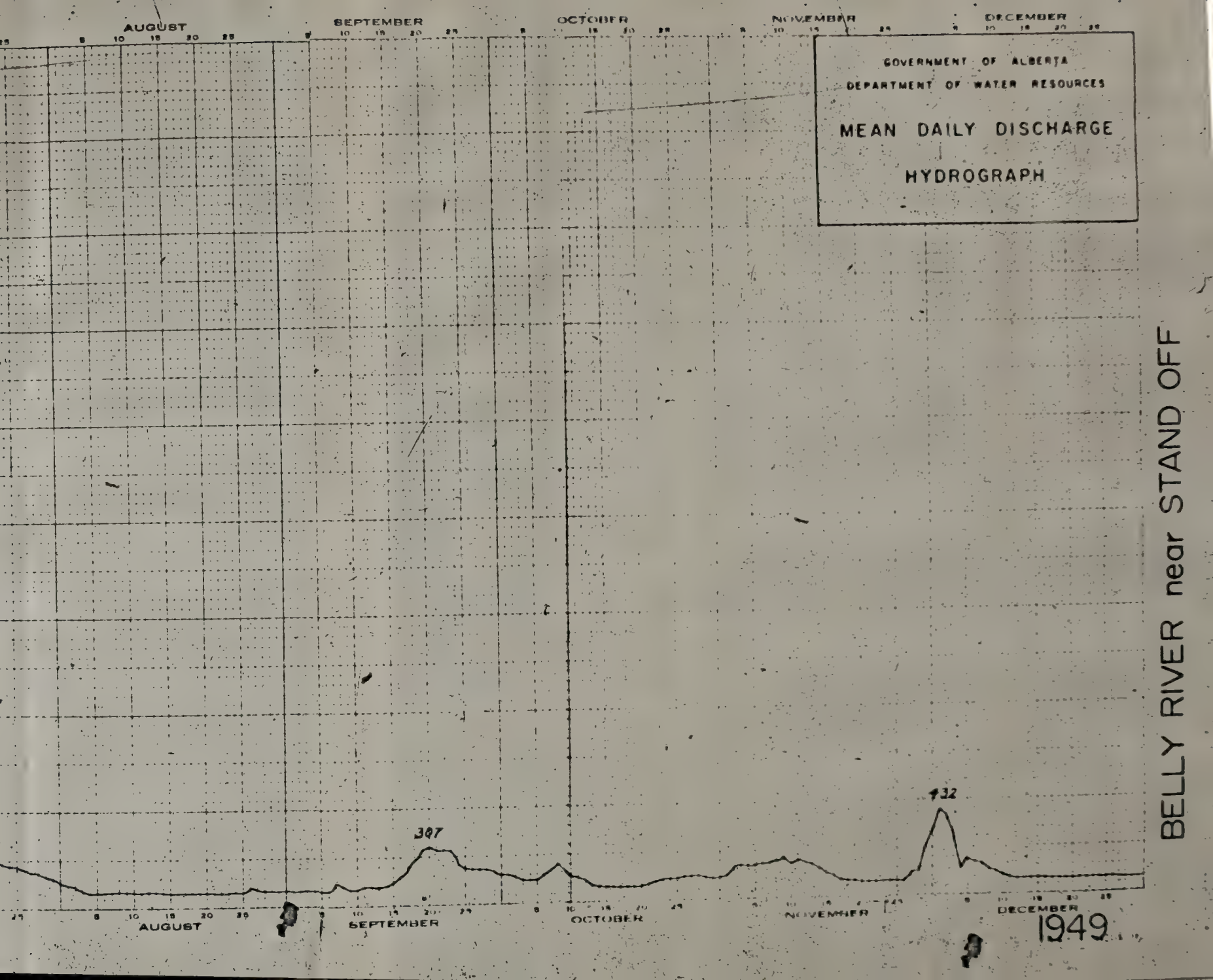
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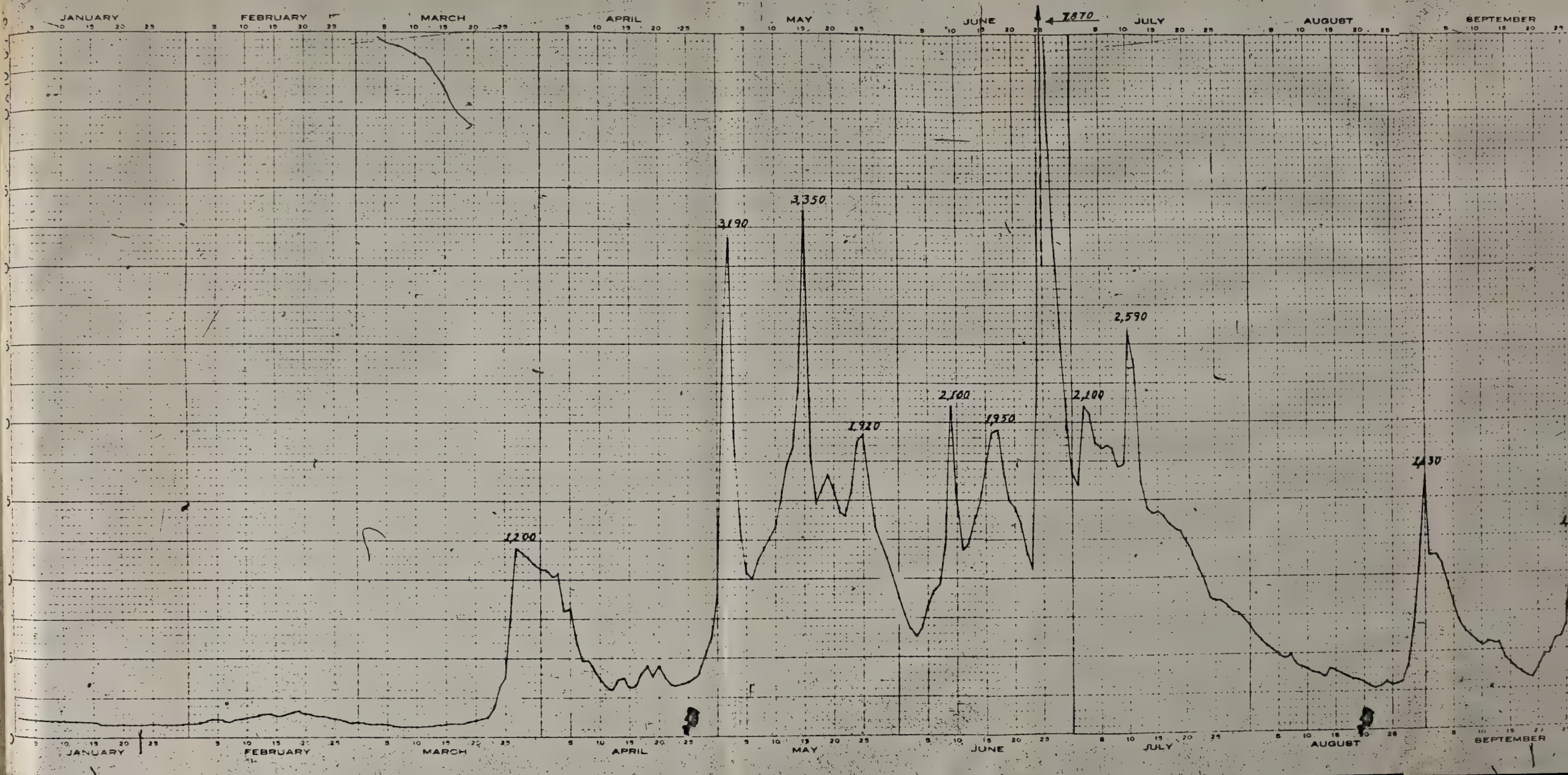
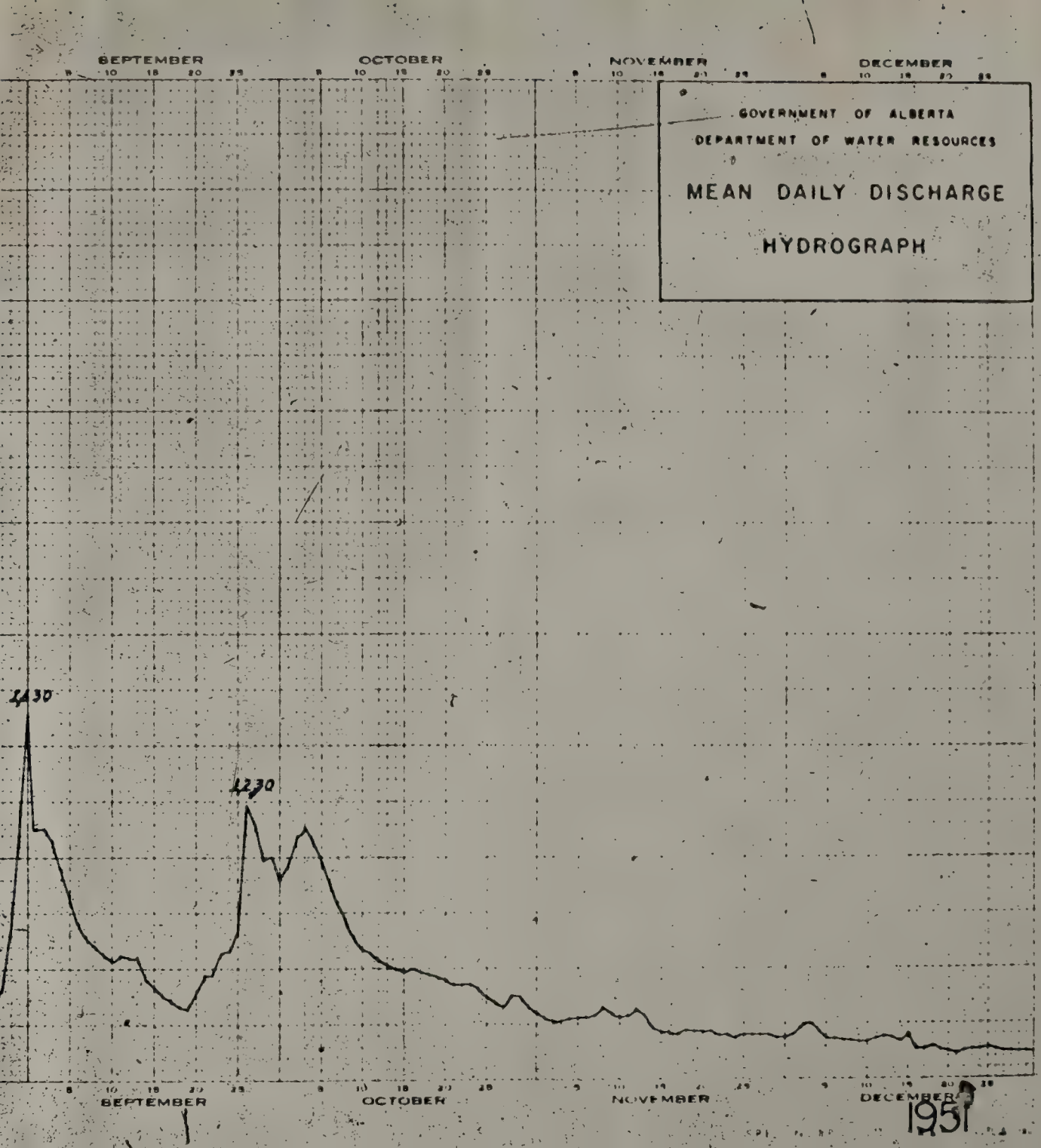
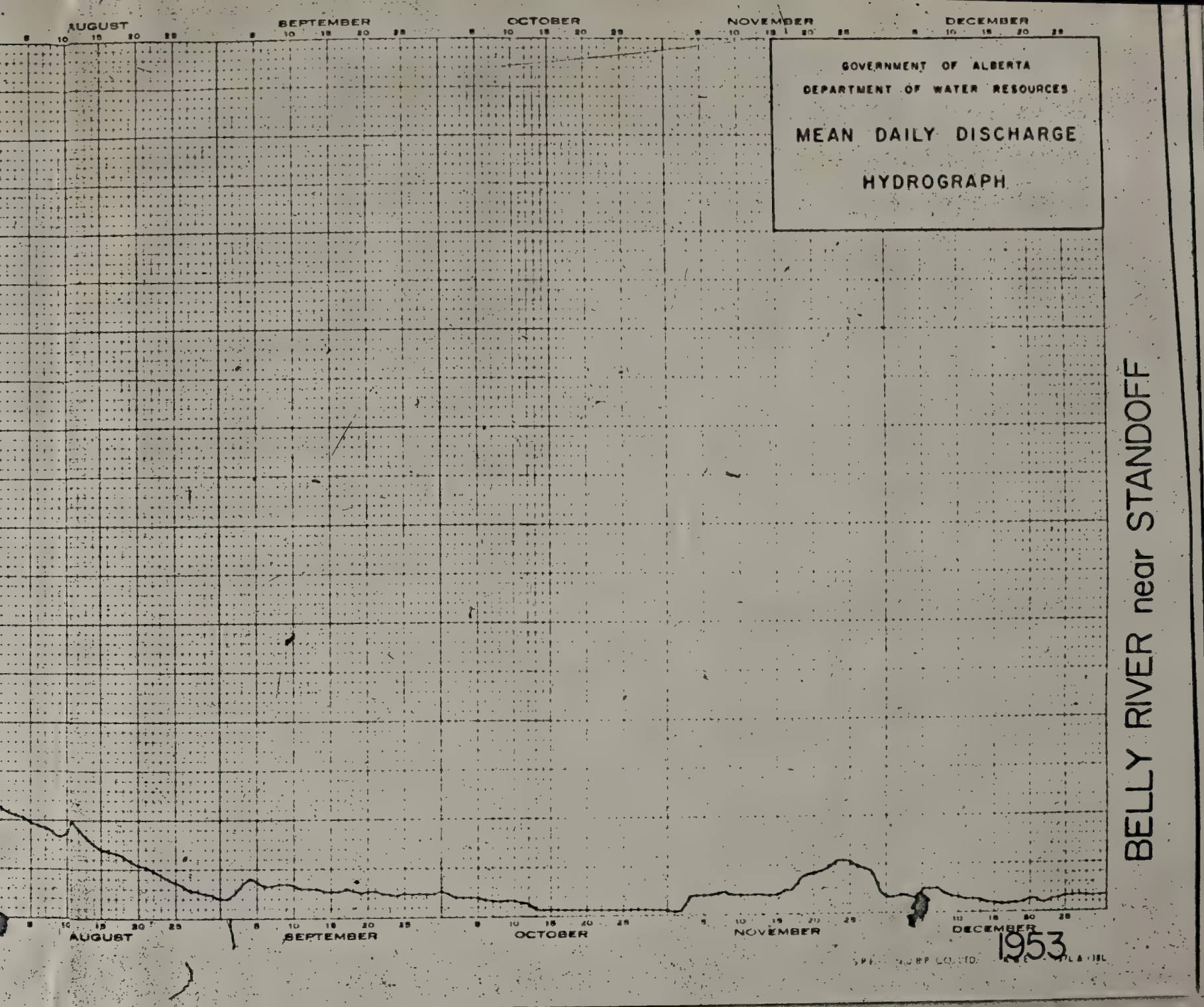
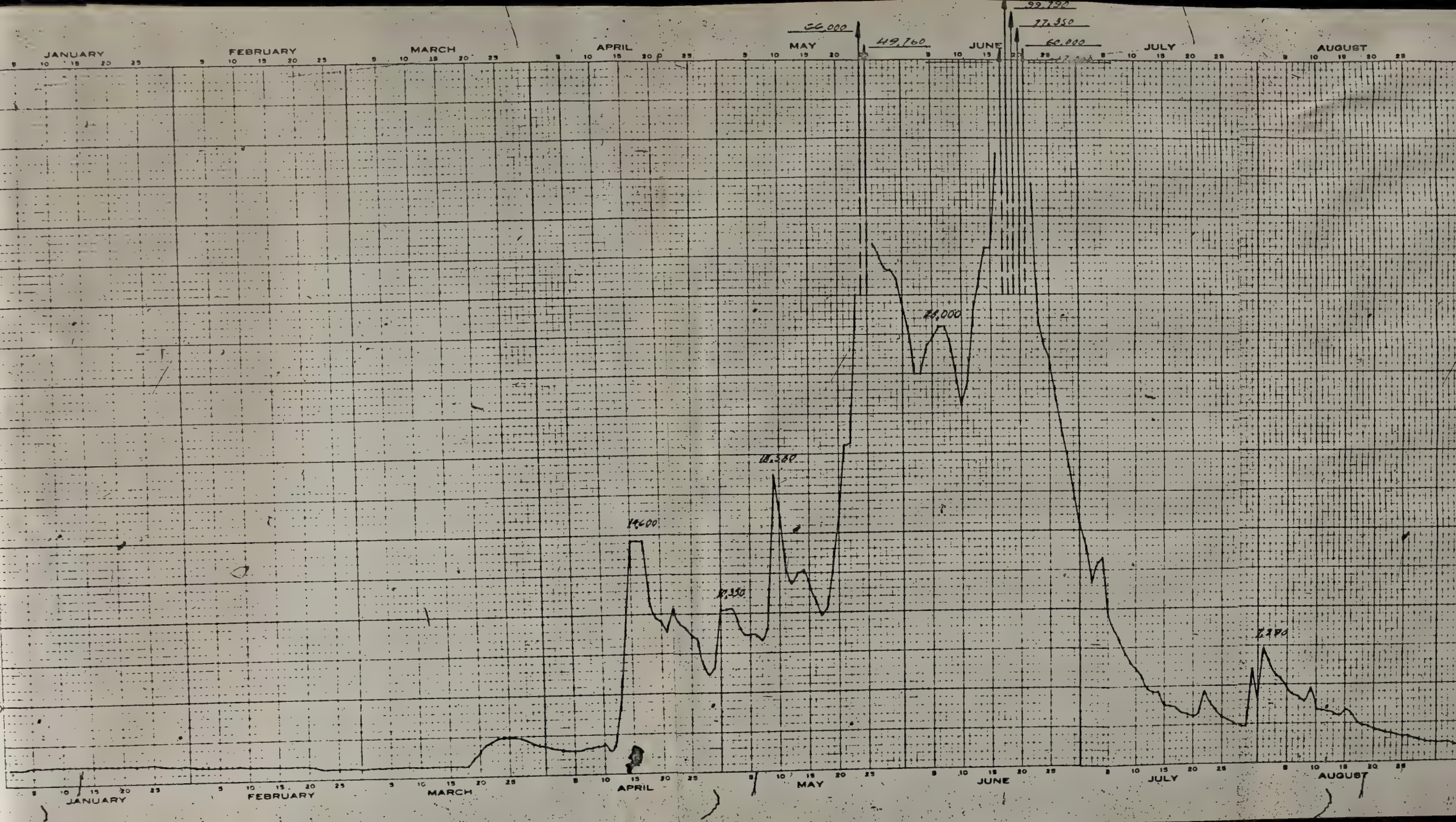
BELLY RIVER near STAND OFF
1949


JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
1870
1,200
3,190
3,350
1,920
2,100
1,950
2,100
2,590
1,430


SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
GOVERNMENT OF ALBERTA
DEPARTMENT OF WATER RESOURCES
MEAN DAILY DISCHARGE
HYDROGRAPH
2430
2230
BELLY RIVER near STAND OFF
1951

X 10³ C.F.S.
0
5
10
15
20
25
30
35
40
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
6370
6200
5690
3570
2260
1490
1150
957
753
423
1420
1470


AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
GOVERNMENT OF ALBERTA
DEPARTMENT OF WATER RESOURCES
MEAN DAILY DISCHARGE
HYDROGRAPH
BELLY RIVER near STANDOFF
1953


JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
66,000
49,760
99,792
27,350
60,000
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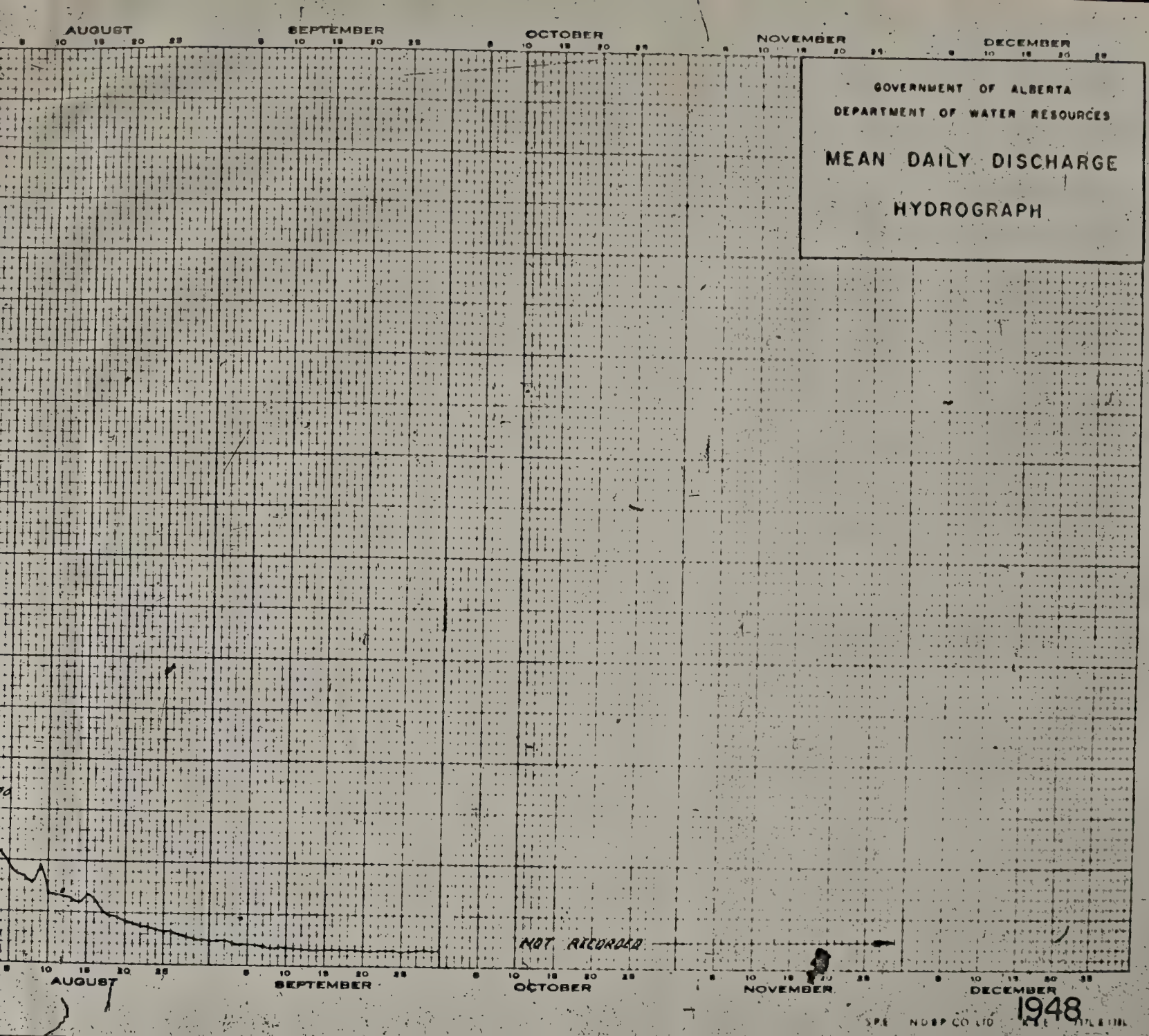
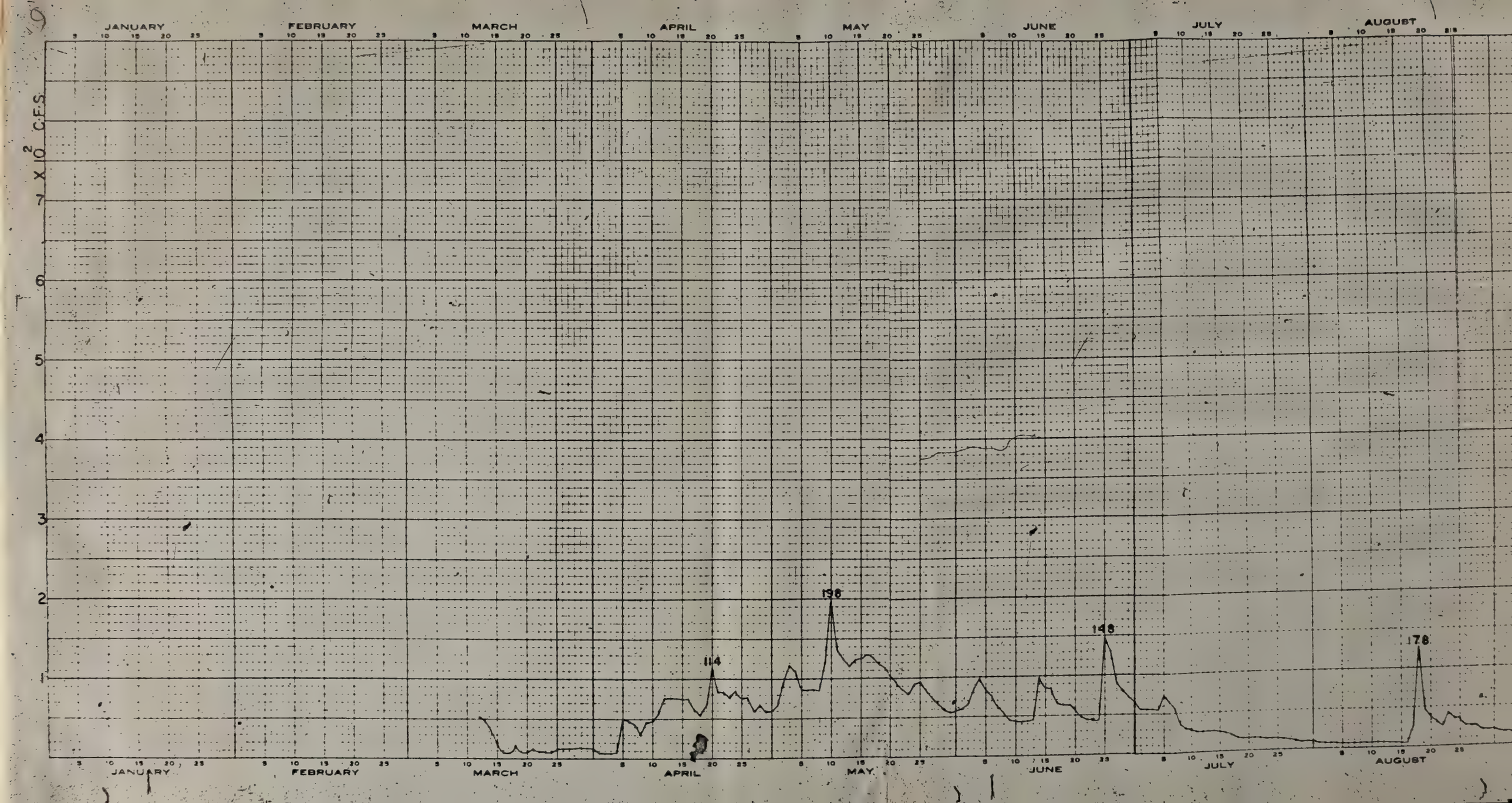
24,000
7,300


AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
GOVERNMENT OF ALBERTA
DEPARTMENT OF WATER RESOURCES
MEAN DAILY DISCHARGE
HYDROGRAPH
NOT RECORDED
OLDMAN RIVER near LETHBRIDGE
1948

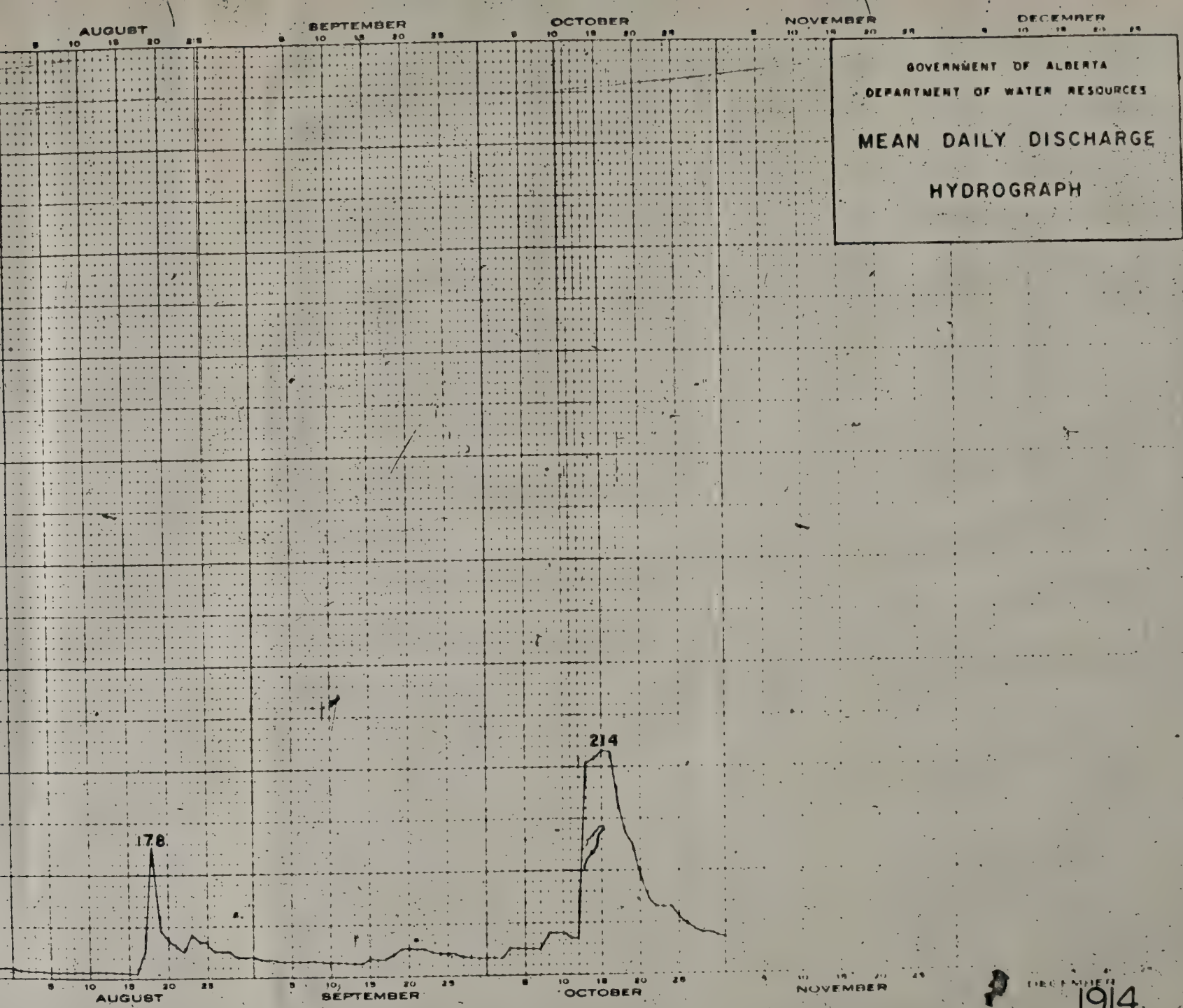

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
X 10² C.F.S.
7
6
5
4
3
2
1
114
198
148
178

GOVERNMENT OF ALBERTA

DEPARTMENT OF WATER RESOURCES

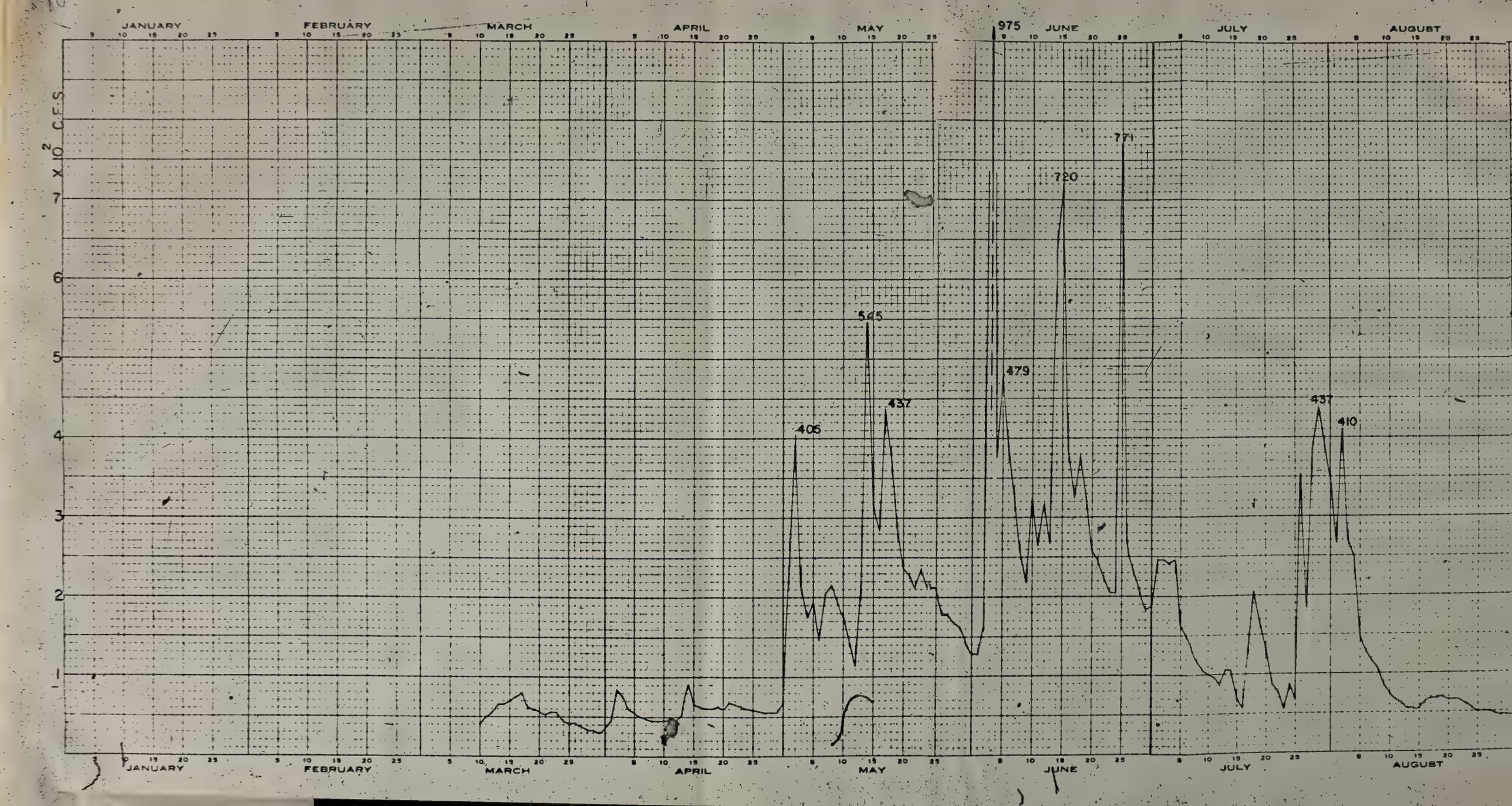
MEAN DAILY DISCHARGE

HYDROGRAPH



1914

PINCHER CREEK at PINCHER CREEK

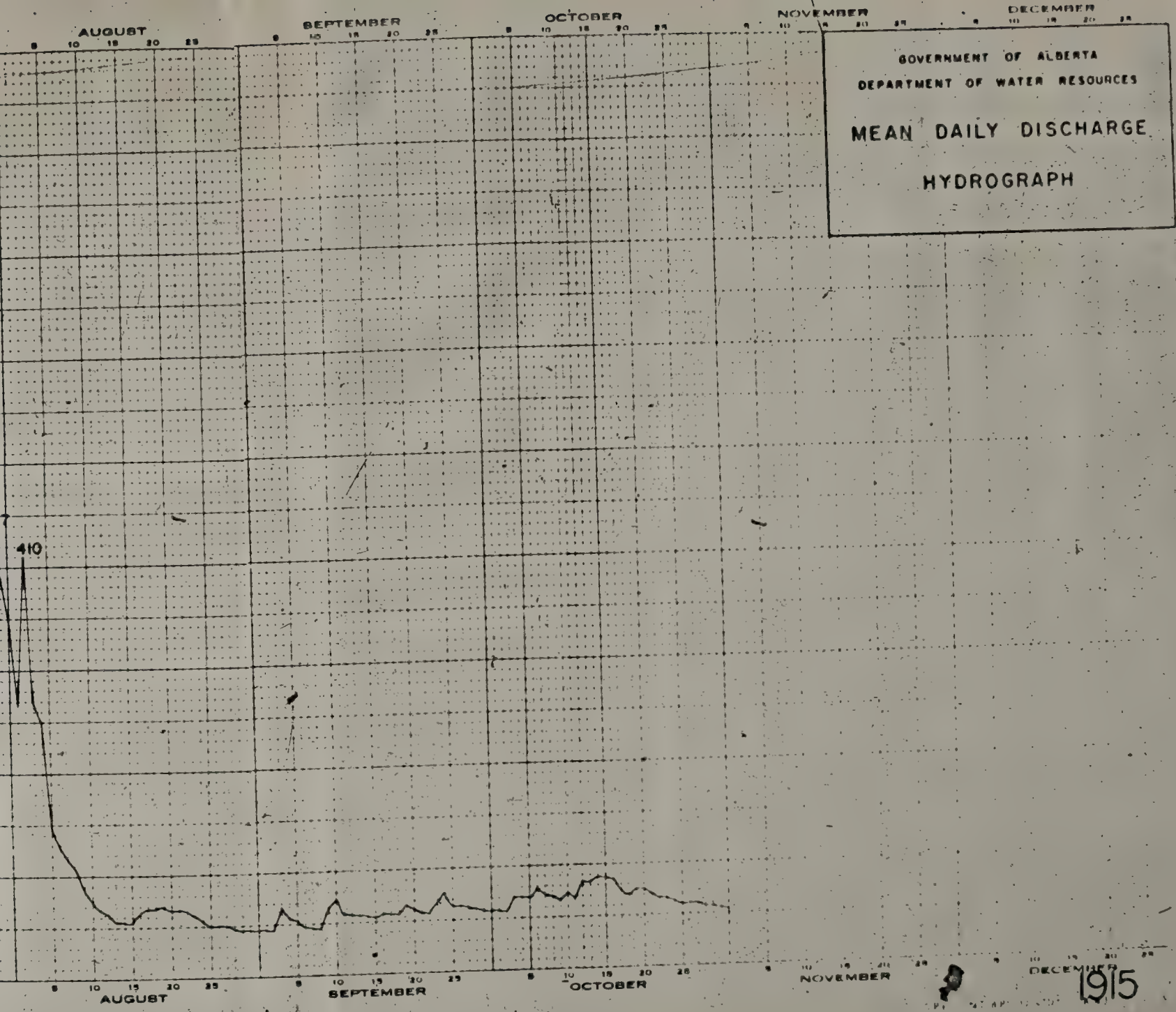

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
X 10² C.F.S.
1
2
3
4
5
6
7
975
771
720
545
479
437
437
410
406

GOVERNMENT OF ALBERTA

DEPARTMENT OF WATER RESOURCES

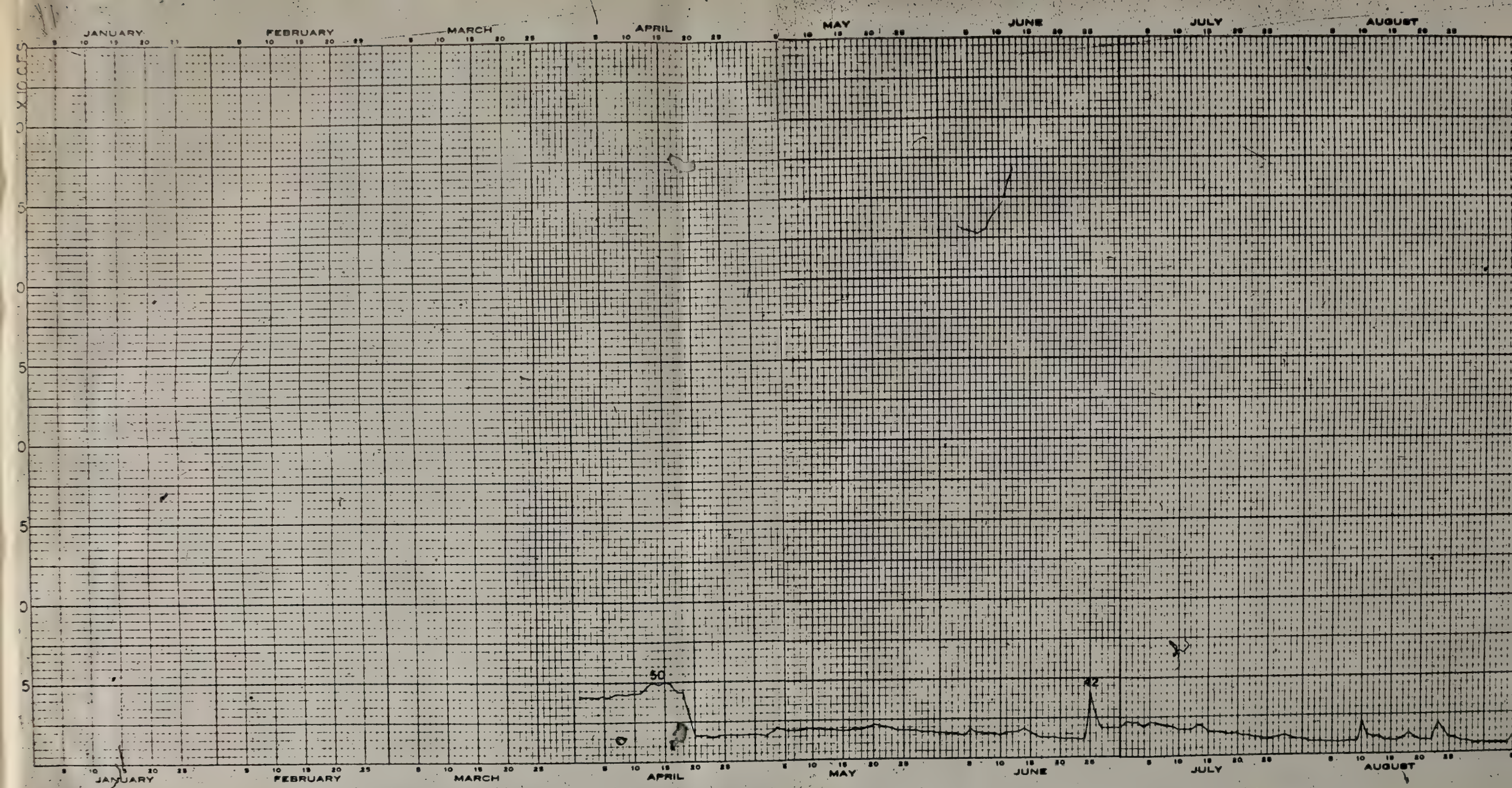
MEAN DAILY DISCHARGE

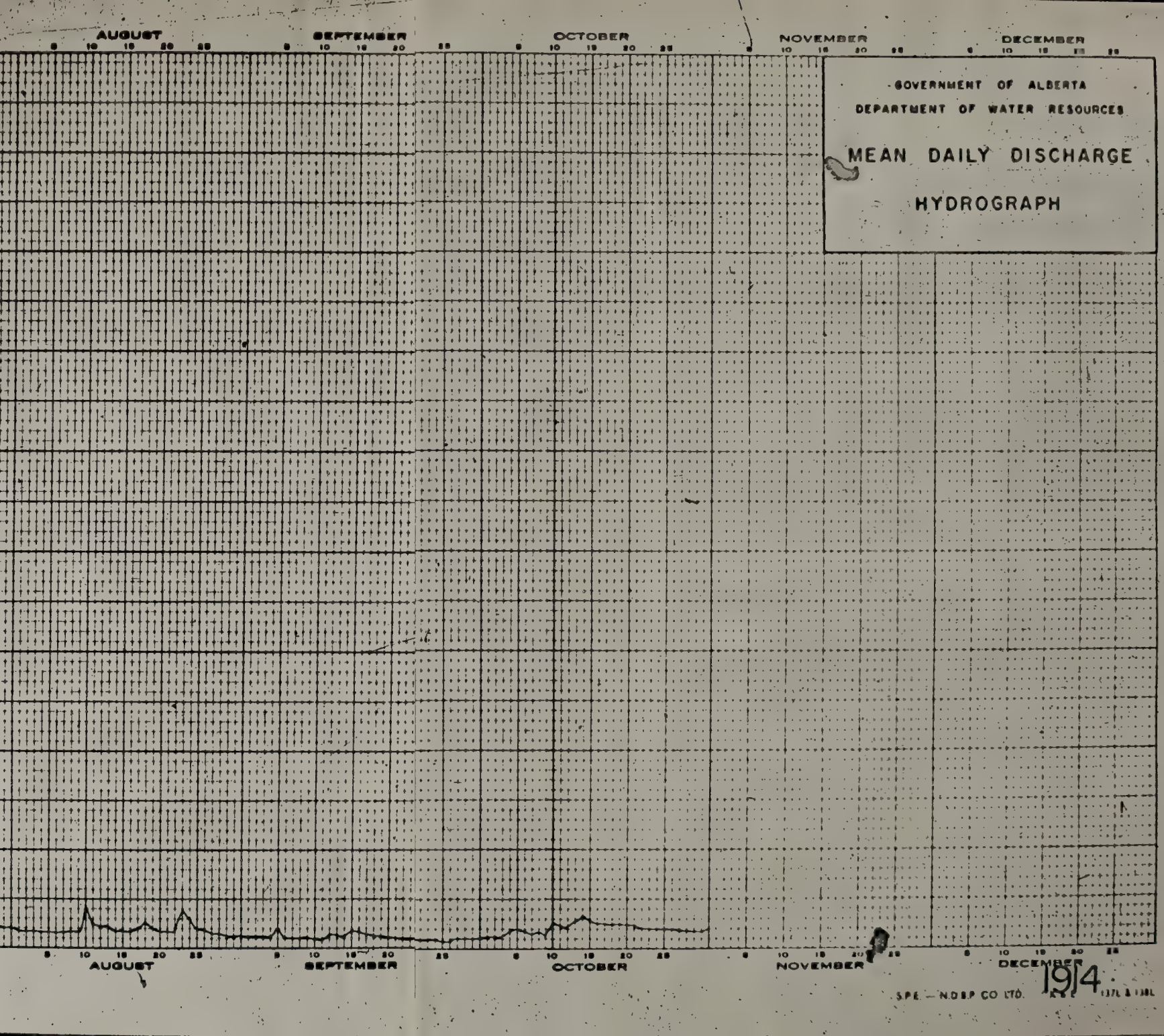
HYDROGRAPH

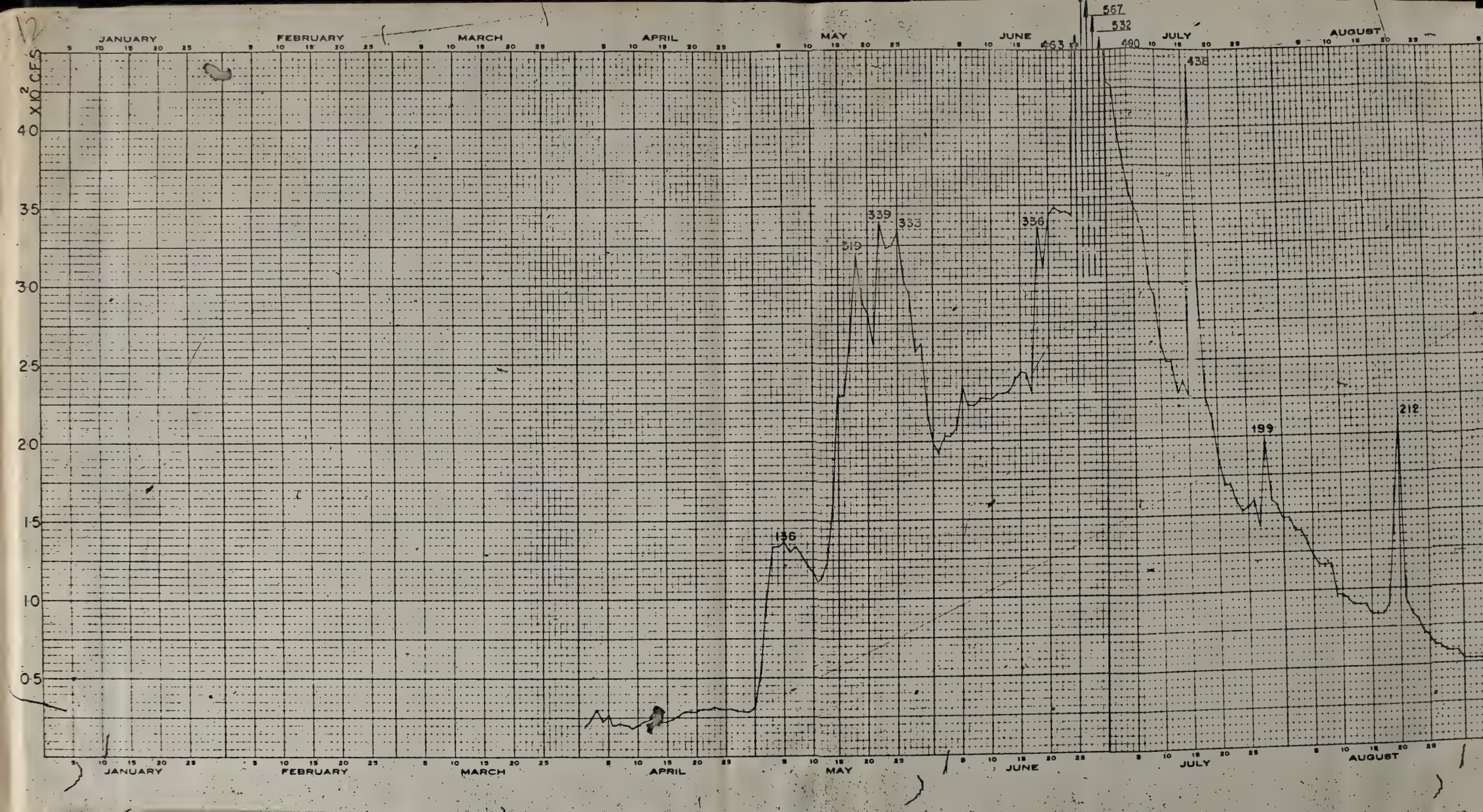


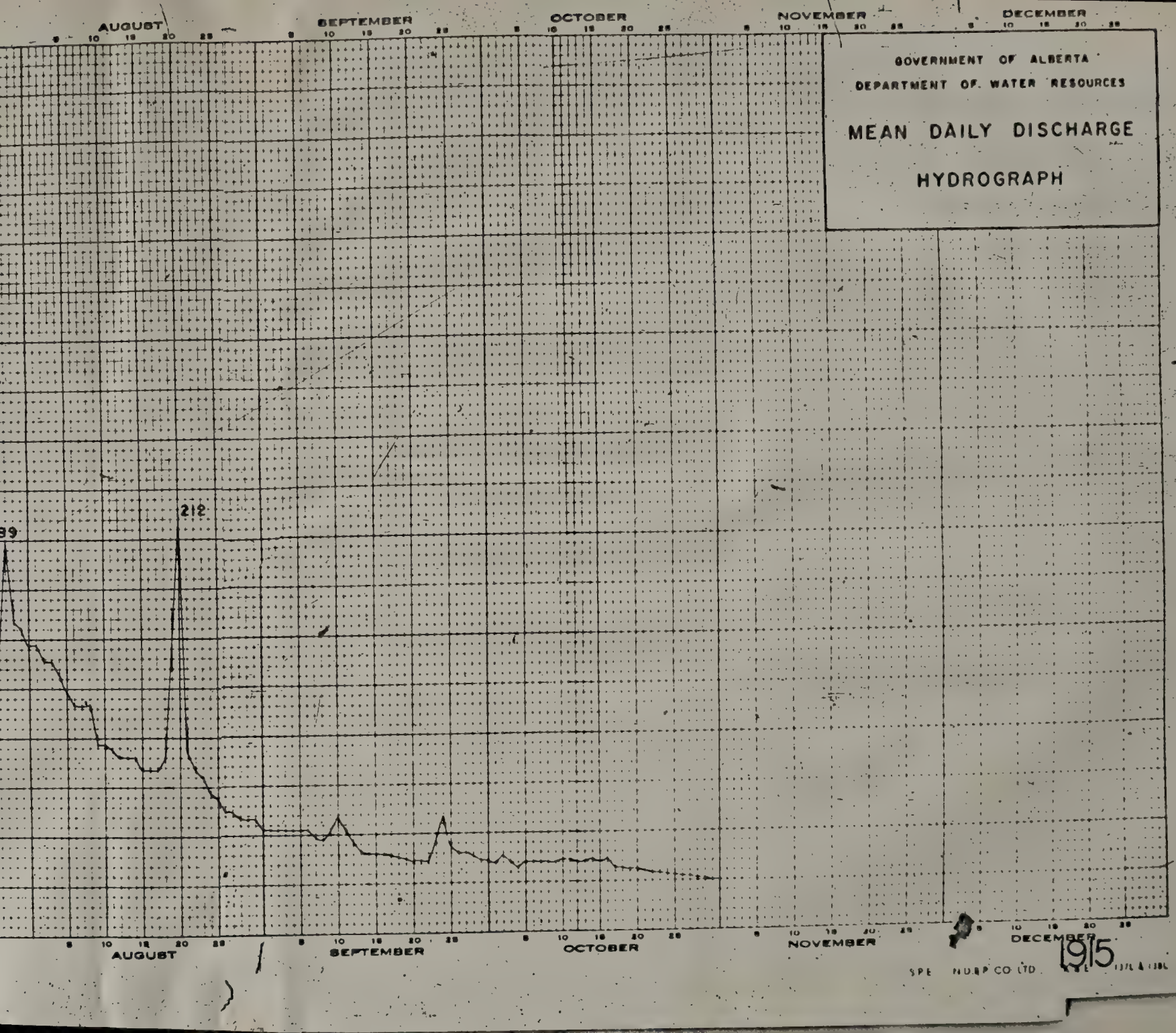
PINCHER CREEK at PINCHER CREEK

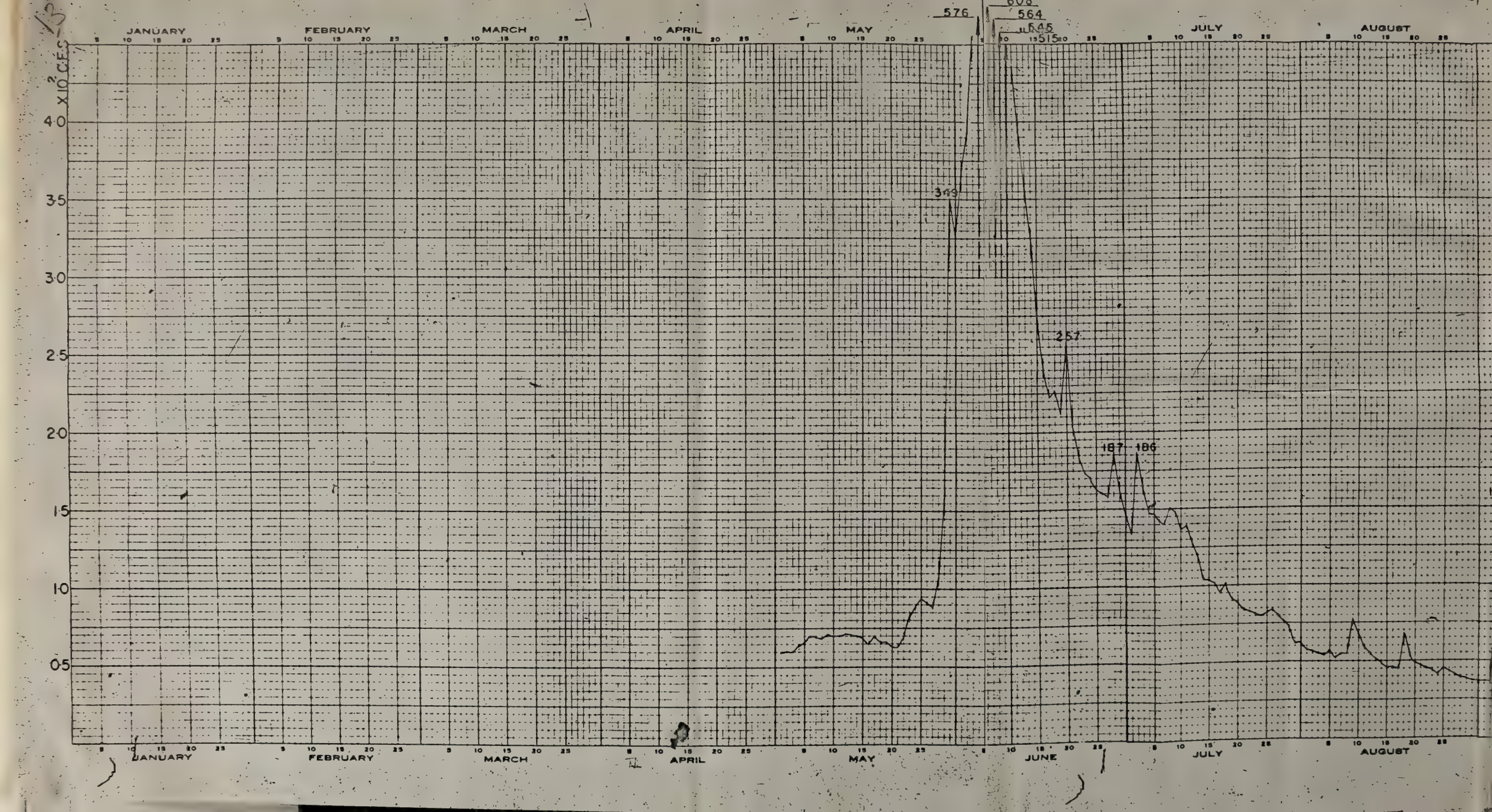
1915

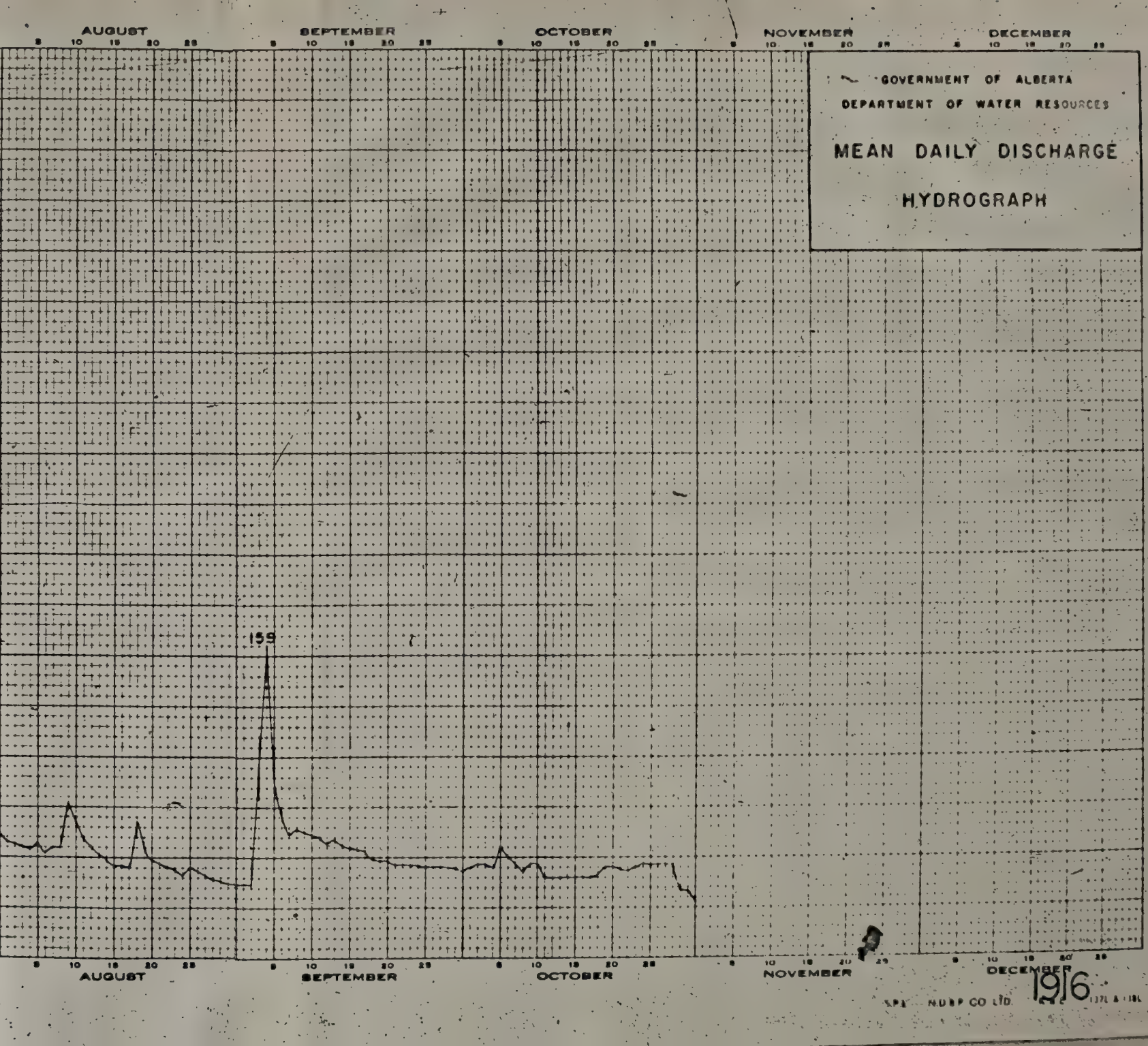

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
X 10 CFS
50
42


AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
GOVERNMENT OF ALBERTA
DEPARTMENT OF WATER RESOURCES
MEAN DAILY DISCHARGE
HYDROGRAPH
TROUT CREEK near LOCKWOOD'S RANCH
1914
S.P.E. — N.D.B.P. CO. LTD.


JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
X10 CFS
4·0
3·5
3·0
2·5
2·0
1·5
1·0
0·5
136
319
339
333
336
463
567
532
490
438
199
212


AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
GOVERNMENT OF ALBERTA
DEPARTMENT OF WATER RESOURCES
MEAN DAILY DISCHARGE
HYDROGRAPH
212
39
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
1915
TROUT CREEK near LOCKWOOD'S RANCH


JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
X10 CFS
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
576
564
545
515
349
257
187
186


AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
GOVERNMENT OF ALBERTA
DEPARTMENT OF WATER RESOURCES
MEAN DAILY DISCHARGE
HYDROGRAPH
159
TROUT CREEK near LOCKWOOD'S RANCH
1916

WATERTON R
STANDOFF
1

CAST. E
BEAVER MINES
2

WATERTON R
3

BELLY R
4

SWIFTCURRENT CR
5

ST MARY R
6

LEE CREEK
7

ST MARY R
8

WILLOW CREEK
CLARESHOLM
10

BELLY R
9

SELECTED MONTHLY FLOWS IN THE OLDMAN RIVER BASIN
SEE APPENDIX III

MEAN DISCHARGE, SECOND FEET
10000
1000
100
10
1
1948-49 SHADED
1952-53 UNSHADED
WATER YEAR OCT - SEPT

B29807